BACHELOR THESIS AND COLLOQUIUM – ME 141502

# EXPLOSION ACCIDENT EVALUATION OF MV. GILI CAT II USING APOLLO ROOT CAUSE ANALYSIS METHODOLOGY

Ricard Diago Sambuaga
NRP 4213 101 046

**Supervisor**
Dr. Eng. Trika Pitana, S.T., M.Sc.
Ir. Dwi Priyanta, M.SE.

**DEPARTMENT OF MARINE ENGINEERING**
**Faculty of Marine Technology**
**Institut Teknologi Sepuluh Nopember**
**Surabaya**
**2017**

**BACHELOR THESIS – ME 141502**

# Explosion Accidents Evaluation of MV. Gili Cat II using Apollo Root Cause Analysis Methodology

Ricard Diago Sambuaga
NRP. 4213 101 046

Supervisors :
Dr. Eng. Trika Pitana, S.T., M.Sc.
Ir. Dwi Priyanta, M.SE

DOUBLE DEGREE PROGRAM OF
MARINE ENGINEERING DEPARTMENT
Faculty of Marine Technology
Institut Teknologi Sepuluh Nopember
Surabaya
2017

*"This page intentionally blank"*

**SKRIPSI – ME 141502**

# Evaluasi Ledakan MV. Gili Cat II Menggunakan Metode *Apollo Root Cause Analysis*

Ricard Diago Sambuaga
NRP. 4213 101 046

Dosen Pembimbing :
Dr. Eng. Trika Pitana, S.T., M.Sc.
Ir. Dwi Priyanta, M.SE

DEPARTEMEN TEKNIK SISTEM PERKAPALAN
PROGRAM GELAR GANDA
Departemen Teknik Sistem Perkapalan
Fakultas Teknologi Kelautan
Institut Teknologi Sepuluh Nopember
Surabaya
2017

*"This page intentionally blank"*

## APPROVAL FORM

**EXPLOSION ACCIDENTS EVALUATION OF MV. GILI CAT II USING APOLLO ROOT CAUSE ANALYSIS METHODOLOGY**

## BACHELOR THESIS

**Submitted to Comply with One of the Requirement to Obtain a Bachelor Engineering Degree of Reliability, Availability, Management, and Safety (RAMS) Laboratory S-1 Program**
**Department of Marine Engineering**
**Faculty of Marine Technology**
**Institut Teknologi Sepuluh Nopember**

**Prepared by:**
**RICARD DIAGO SAMBUAGA**
**NRP. 4213 101 046**

**Approved by**
**Head of Marine Engineering Department:**

**Dr. Eng. M. Badrus Zaman, S.T., M.T**
**NIP. 1977 0802 2008 01 1007**

*"This page intentionally blank"*

## APPROVAL FORM

**EXPLOSION ACCIDENTS EVALUATION OF MV. GILI CAT II USING APOLLO ROOT CAUSE ANALYSIS METHODOLOGY**

## BACHELOR THESIS

**Submitted to Comply with One of the Requirement to Obtain a Bachelor Engineering Degree of Reliability, Availability, Management, and Safety (RAMS) Laboratory S-1 Program**
**Department of Marine Engineering**
**Faculty of Marine Technology**
**Institut Teknologi Sepuluh Nopember**

**Prepared By:**
**RICARD DIAGO SAMBUAGA**
**NRP. 4213 101 046**

**Approved by supervisors:**

1. **Dr. Eng Trika Pitana, S.T., M.Sc.** ( )
   **NIP. 1976 0129 2001 12 1001**

2. **Ir. Dwi Priyanta, M.SE** ( )
   **NIP. 1968 0703 1994 02 1003**

*"This page intentionally blank"*

## APPROVAL FORM

**EXPLOSION ACCIDENTS EVALUATION OF MV. GILI CAT II USING APOLLO ROOT CAUSE ANALYSIS METHODOLOGY**

## BACHELOR THESIS

**Submitted to Comply with One of the Requirement to Obtain a Bachelor Engineering Degree of Reliability, Availability, Management, and Safety (RAMS) Laboratory S-1 Program**
**Department of Marine Engineering**
**Faculty of Marine Technology**
**Institut Teknologi Sepuluh Nopember**

**Prepared by:**
**RICARD DIAGO SAMBUAGA**
**NRP. 4213 101 046**

**Approved by**
**Representative Hochschule Wismar in Indonesia:**

**Dr.-Ing Wolfgang Busse**

*"This page intentionally blank"*

# DECLARATION OF HONOR

I, who signed below hereby confirm that:

***This final project report has written without any plagiarism act, and confirm consciously that all the data, concepts, design, references, and material in this report own by Reliability, Availability, Management, and Safety (RAMS) in Department of Marine Engineering ITS which are the product of research study and reserve the right use for further research study and its development.***

| | |
|---|---|
| Name | : Ricard Diago Sambuaga |
| NRP | : 4213 101 046 |
| Bachelor Thesis Title | : Explosion Accidents Evaluation of MV. Gili Cat II Using Apollo Root Cause Analysis Methodology |
| Department | : Double Degree Program in Marine Engineering |

If there is plagiarism act in the future, I will fully responsible and receive the penalty given by ITS according to the regulation applied.

Surabaya, July 2017

Ricard Diago Sambuaga

*"This page intentionally blank"*

# ABSTRACT

## EXPLOSION ACCIDENTS EVALUATION OF MV. GILI CAT II USING APOLLO ROOT CAUSE ANALYSIS METHODOLOGY


**Name** : **Ricard Diago Sambuaga**
**NRP** : **4213 101 046**
**Department** : **Marine Engineering**
**Supervisor** : **Dr. Eng. Trika Pitana, S.T., M.Sc**
**Ir. Dwi Priyanta, M.SE**


### Abstract


*The highest percentage of accident investigation (2007-March 2017) of National Transportation Safety Committee (NTSC) is caused by fire or explosion (38%). MV. Gili Cat II had been exploded September 15th, 2016 at Padangbai port, Bali. MV. Gili Cat II is a passenger ship that serves from Padangbai Port, Bali to Gili Ketapang, Lombok. There were 35 passengers on board when ship was exploded. From this accident, there were 2 passengers got fatalities. Related to the explosion of MV. Gili Cat II, Root Cause Analysis and giving recommendation is needed (especially for electrical system and fuel oil system). Apollo Root Cause Analysis that used in this thesis. This is recommended for event / incident-based items of complex and higher significance. Recommendation of this thesis is referring the NCVS (Non-Conventional Vessel Standard) Ch. V and NFPA refueling procedures. As the result of the analysis, the explosion is caused by bad electrical wiring system, static electricity around the tank and hull, there is no earthing system of the vessel, there was a fuel spill when refueling, venting pipe was not following standard, and using inappropriate materials, compartment below deck was not watertight and only using a spot welding on MV. Gili Cat II was found. The following recommendations related to Electrical system are earthing system should be fitted, battery should be mounted properly to prevent movement of the battery cause the motion of the vessel. The following recommendations related to Fuel oil system are material of flexible pipe is using SAE J 30 or equivalent, venting system shall be following standard, using an appropriate pump for filling the tank and done safely, tanks should be earthed, and follow the refueling procedures by NFPA.*



*Keywords: MV. Gili Cat II, Apollo Root Cause Analysis (ARCA), electrical system, fuel oil system*

*"This page intentionally blank"*

# ABSTRAK

## EVALUASI LEDAKAN MV. GILI CAT II MENGGUNAKAN METODE *APOLLO ROOT CAUSE ANALYSIS*

**Name** : **Ricard Diago Sambuaga**
**NRP** : **4213 101 046**
**Jurusan** : **Teknik Sistem Perkapalan**
**Dosen Pembimbing** : **Dr. Eng. Trika Pitana, S.T., M.Sc**
**Ir. Dwi Priyanta, M.SE**

### Abstrak

*Persentase tertinggi dari investigasi kecelakaan (2007-Maret 2017) dari Komite Nasional Keselamatan Transportasi (KNKT) disebabkan oleh kebakaran atau ledakan (38%). MV. Gili Cat II telah meledak 15 September 2016 di pelabuhan Padangbai, Bali. MV. Gili Cat II merupakan kapal penumpang yang melayani penyebrangan antara Pelabuhan Padangbai, Bali sampai Gili Ketapang, Lombok. Terdapat 35 penumpang di kapal pada saat kapal meledak. Dari kecelakaan ini, ada 2 penumpang yang menjadi korban jiwa. Terkait dengan ledakan MV. Gili Cat II, Root Cause Analysis dan pemberian rekomendasi sangat dibutuhkan (terutama untuk sistem kelistrikan dan sistem bahan bakar). Apollo Root Cause Analysis merupakan metode yang digunakan dalam skripsi ini. Metode ini direkomendasikan untuk kejadian / kejadian berdasarkan item yang kompleks dan signifikan tinggi. Rekomendasi pada tesis ini mengacu pada NCVS (Non-Conventional Vessel Standard) Ch.V dan NFPA refueling procedures. Adapun hasil analisis dari ledakan tersebut disebabkan oleh sistem kabel listrik yang buruk, listrik statis di sekitar tangki dan lambung, tidak ada sistem pembumian kapal, ada tumpahan bahan bakar saat mengisi bahan bakar, pipa ventilasi tidak mengikuti standar, dan material yang digunakan tidak tepat, kompartemen di bawah dek tidak kedap udara dan hanya menggunakan pengelasan titik pada MV. Gili Cat II . Rekomendasi berikut yang terkait dengan sistem kelistrikan adalah sistem pembumian harus dipasang, baterai harus terpasang dengan benar untuk mencegah pergerakan baterai terhadap pergerakan kapal. Rekomendasi berikut yang terkait dengan sistem bahan bakar adalah material dari pipa fleksibel menggunakan SAE J 30 atau yang setara, sistem ventilasi harus mengikuti standar, penggunakan pompa yang sesuai untuk mengisi tangki dan dilakukan dengan*

*aman, tangki harus dibumikan, dan mengikuti prosedur pengisian bahan bakar oleh NFPA.*

*Kata kunci: MV. Gili Cat II, Apollo Root Cause Analysis (ARCA), sistem kelistrikan, sistem bahan bakar*

# PREFACE

Thanks to Allah SWT for everything that have given to me, which has given guidance so the Bachelor Thesis title "Explosion Accidents Evaluation of MV. Gili Cat II Using Apollo Root Cause Analysis Methodology "can be done properly. In completing this Bachelor Thesis, I cannot do it alone. Therefore, I would like to thank those who helped the author in completing this Bachelor Thesis, among others;

1. Thanks to Allah Subhanahu Wata'ala for all your greatness, so writer can finish this bachelor thesis. Also thanks to The Prophet Muhammad SAW who leads us as a muslim to the right path.
2. Thanks to the author Family, especially for the author parents. Mr. Ansori and Mrs. Ramiyah who always give their prayer, support, loves, and encouragement for everything in the author live. Also for the author sisters and brother Intania Andra Yani, Safira Aditya Lestari and Zacky Maulana Raihansyah who always give the author encourage and support to finish this bachelor thesis.
3. Mr. Dr. Eng. Muhammad Badrus Zaman, ST., MT. as the Head of Marine Engineering Department.
4. Mr. Prof. Semin, ST., MT., Ph.D as the Secretary of Marine Engineering Department.
5. Dr. Sutopo Purwono Fitri, S.T., M.Eng. as the author Lecturer Advisor in Department of Marine Engineering since the first semster.
6. Dr. Eng. Trika Pitana, S.T., M.Sc., as the author first supervisor in Bachelor Thesis who has giving the author his support, ideas, correction, also guidance for the author bachelor thesis.
7. Ir. Dwi Priyanta, M.SE., as the author second supervisor in Bachelor Thesis who has giving the author his support, ideas, correction, also guidance for the author bachelor thesis.
8. Dr. -Ing. Wolfgan Busse as Representative Hochschule Wismar in Indonesia who has giving the author his support, guidance, and important information.
9. Mr. A.A. Bagus Dinariyana Dwi P., ST., MES., Ph.D as the Head of RAMS Laboratory who has giving permission to do any activities inside the laboratory and provides place during the working of bachelor thesis.
10. Prof. Ketut Buda Artana, S.T., M.Sc, . Dr. I Made Ariana, ST., MT., and Dr. Dhimas Widhi Handani, ST., M.Sc as the author supervisors in Reliability, Availability, Management, and Safety (RAMS) Laboratory who has giving

their support, ideas, opportunity for the author bachelor thesis and giving permission to for any activities in laboratory.

11. All the author lecturers in Department of Marine Engineering, Institut Teknologi Sepuluh Nopember (ITS) who has giving their support, guidance, and ideas.
12. Mr. Aleik Nurwahyudy, one of the Investigator of the Indonesian National Transportation Safety Committee (NTSC) as the author mentor of the author research. Thank you for your support by explaining seveal condition, chronology, etc. in the author research study (Explosion of MV. Gili Cat II).
13. Indonesian NTSC for letting the author take data and an opportunity to discuss about accidents in Indonesia especially for MV. Gili Cat II Explosion.
14. Emthe author Pratiwi, S.T., Fadilla Indrayuni Prastyasari, S.T., M.Sc., Ayudhia Pangestu Gusti, S.T., Putri Dyah Setyorini, S.T., and Gede Bagus Dwi Suasti Antara, S.T., M.M.T., as the author mentors during the author research study.
15. Alphie Benhard S. M. M, Danuja WIjayanto, Kevin Kurniawan, Zein Arfian, Nyimas Safira Amalia, I Gde Manik Sukanegara, Miranto Anggriawan P, Hilda Gloria, Dante Taufiq Akbar, Filik Trisilo, Thariq Arafatul Akbar, Syahnan Ardi Azharie M, and Bernadita Suryawati who always give their support, happiness, and ideas so the writer can finish this bachelor thesis.
16. All RAMS Laboratory of Marine Engineering Department, ITS members who helped a lot in finishing or preparing to the final project presentation.
17. Friends and member of National Ship Design and Engineering Centre (NASDEC) ITS who always give their support, happiness, and ideas so the writer can finish this bachelor thesis.
18. Marine Engineering "BARAKUDA 2013" who helped a lot in finishing or preparing to the final project presentation.

This final project still a lot of deficiency. Therefore, any comments or suggestions are welcome for completing this final project. Last, the writer hope that this final project will have benefit to the readers.

Surabaya, July 2017

Ricard Diago Sambuaga

# Table of Contents

# List of Figure

# List of Table

*"This page intentionally blank"*

# CHAPTER 1
# INTRODUCTION

## 1.1 Research Background

Sea transportation is very important in human life. Ships are useful to connect us from one island to the other island. Ship is also useful as a means of transportation to ship a variety of human needs. However, Safety level of ship is one of concern because nowadays we often hear nor see all sorts of news about ship accidents. Safety is the most important things that must be addressed so that the ship accidents can be minimized or prevented. Until now, various national and international organizations continue to improve on the safety regulations of ship. Improvements are referred to accidents that have occurred previously such as construction problems, fire detection, safety equipment, evacuation procedures, training conducted for the crew, etc. Table 1. 1 shows the data of ships that have been investigated by NTSC (National Transportation Safety Committee) in 2007 – March 2017. The main causes of accidents are Fire / explosions aboard the ship. Figure 1. 1 shows ship accidents percentage diagram from Table 1. 1 data.

*Table 1. 1 Vessels data were investigated by NTSC Year 2007 – March 2017*[1]

| No | Year | Number of Accidents | Accidents | | | | Fatalities | |
|---|---|---|---|---|---|---|---|---|
| | | | Sink | Fire / Exploded | Collision | Others | Death / Missing | Wounds |
| 1 | **2007** | 7 | 4 | 3 | 0 | 0 | 100 | 104 |
| 2 | **2008** | 5 | 2 | 3 | 0 | 0 | 10 | 51 |
| 3 | **2009** | 4 | 2 | 1 | 1 | 0 | 447 | 0 |
| 4 | **2010** | 5 | 1 | 1 | 3 | 0 | 15 | 85 |
| 5 | **2011** | 6 | 1 | 3 | 2 | 0 | 86 | 346 |
| 6 | **2012** | 4 | 0 | 2 | 2 | 0 | 13 | 10 |
| 7 | **2013** | 6 | 2 | 2 | 2 | 0 | 65 | 9 |
| 8 | **2014** | 7 | 2 | 3 | 2 | 0 | 22 | 4 |
| 9 | **2015** | 11 | 3 | 4 | 3 | 1 | 85 | 2 |
| 10 | **2016** | 18 | 6 | 4 | 3 | 5 | 31 | 18 |

[1] NTSC Accidents Data Year 2007 – March 2017

| No | Year | Number of Accidents | Accidents | | | | Fatalities | |
|---|---|---|---|---|---|---|---|---|
| | | | Sink | Fire / Exploded | Collision | Others | Death / Missing | Wounds |
| 11 | **2017** | 4 | 1 | 3 | 0 | 0 | 24 | 0 |
| **Total** | | 77 | 24 | 29 | 18 | 6 | 898 | 629 |

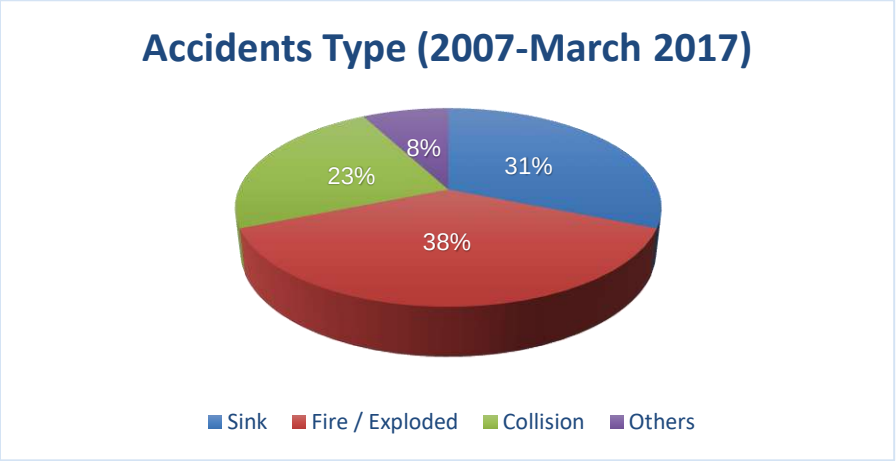



*Figure 1. 1 Ship Accidents Percentage diagram* [2]

From the statistical data above, we can see that Fire / explosions are the most frequent accidents in Indonesia. MV. Gili Cat II had been exploded on Thursday, September 15th, 2016. MV. Gili Cat II was departed from Padangbai, Bali to Gili Trawangan, Lombok. An accident occurred at 09.35 near of Padangbai Port, Bali. There were 35 passengers onboard when ship exploded. MV. Sondex 1 help MV. Gili Cat II to pull the vessel to Pier 3 Padangbai Port. From this accident, there were 2 passengers got fatalities. Figure 1. 2 is a picture of MV. Gili Cat II.

[2] NTSC Accidents Data Year 2007 – March 2017

*Figure 1. 2 MV. Gili Cat II* [3]

This thesis will be investigated to determine the cause of explosion on MV. Gili Cat II. Investigations were carried begins with Root Cause Analysis RCA). Apollo Root Cause Analysis (ARCA) – RealityCharting is used in this thesis. Root cause Analysis is a wide variety method used to identify the main causes of problems (tracing problem to their origin). RCA also can helps answer the question of why the problem happened in the first place, which in turn, and can helps us to prevent the recurrence. ARCA is recommended for event / incident-based items of complex and higher significance. RealityCharting is a simple causal process whereby one asks why of a defined problem, answers with at least two causes in the form of an action and condition. Then asks why of each answer and continues asking why of each stated cause until there are no more answers. The answer or causes is supported with evidence or use "?". To complete the apollo root cause analysis, there are 4 steps that should be followed. Four steps that should be followed are: Define the problem, Create Reality or Cause-Effect Chart (Chart is created supported with evidence), Identify possible effective solution, implement best solution and finalize the report.

After analyzing the root cause of the accidents, next stage is recommending an electrical system and fuel oil system regarding the existing condition by following standard. Recommendation of fuel oil system and electrical system are action to prevent explosion of MV. Gili Cat II. System recommendation of this thesis is according to NCVS (Non-Conventional Vessel Standard) and NFPA. FOS and Electrical system recommendation already complete, it can use for preventing similar case or it can be used for other parties.

[3] MV. Gili Cat II NTSC Draft Report, 2016

## 1.2 Problem Statement

From the explanation above, so the main problem will be discussed is as followed.

1. How to determine the root cause of the explosions using ARCA?
2. How is the recommendation of fuel oil system of an outboard engine?
3. How is the recommendation of electrical system of an outboard engine?

## 1.3 Research Objectives

The objectives of this study are followings.

1. To reanalyze the root cause of the explosions on the ship.
2. To evaluate fuel oil system of an outboard engines according to NCVS.
3. To evaluate electrical system of an outboard engines according to NCVS.

## 1.4 Research Contribution

The Contribution of this study are followings.

1. Provide recommendation of fuel oil system of an outboard engines.
2. Provide recommendation of electrical system of an outboard engine.
3. Could be used for related parties to determine the act of prevention and mitigation of explosions on allied ships.

## 1.5 Research Limitation

For this thesis can be focused and organized, then made a couple of limitations problem as follows.

1. Research on the ship of MV. Gili Cat II.
2. Research on analysis and evaluation of explosion on board, focusing on root cause analysis of explosion from the deck.
3. Evaluate design only for fuel oil system and electrical system.

# CHAPTER 2
# LITERATURE STUDY

## 2.1 Research Objectives

### 2.1.1 MV. Gili Cat II Description

MV. Gili Cat II is a passenger ship that serves from Padangbai (Bali) to Gili Trawangan (Lombok). This ship constructed in Australia in 2001. MV. Gili Cat II has a main material using an Aluminum. In 2013, PT. Indonusa Segara Marine defined as companies holding ISM certificates. MV. Gili Cat II operated by PT. Samudera Ekspedisi Aman in 2014. Figure 2. 1 below shows MV. Gili Cat II Condition. MV. Gili Cat II have general data as follows:

- Length Overall : 11,69 m
- Breadth Molded : 3,42 m
- Draught : 0,60 m
- Depth : 0,90 m
- Gross Tonnage : 6 T
- Net Tonnage : -
- Type : Passenger Ship
- Flag : Indonesia
- Production Year : 2001
- Production Location : Australia
- Construction Material : Aluminum

*Figure 2. 1 MV. Gili Cat II* [1]

[1] MV. Gili Cat II NTSC Draft Report, 2016

This ship does not have a certificate for a class like a machine certificate and hull. MV. Gili Cat II is a ship with a single hull (monohull). This boat can carry 35 passengers with 4 crews. The controller for steer and Revolution Per Minute (RPM) lever are located at the navigation space. Control consoles are installed aboard also with other indicators as well. Deck of the ship using aluminum plate are installed semi-permanently, especially on the stern of accommodation space which aims to simplify the maintenance and troubleshoot of the lower deck.

MV. Gili Cat II uses 3 units of outboard engines type Suzuki DF300 4 stroke types with power of 300 HP. Ship engine configuration have a maximum rotation will be able to provide power to the ship's speed reached to 45 knots. But the ship operates at an average speed of 20-25 knots (Padangbai - Gili Trawangan can be reached within 1.5 hours). Fuel ship engines using gasoline, but in the last 3 months aboard using a fuel mixture of gasoline and pertalite.

Maximum fuel tank capacity of 1500 liters (this tank has been modified with the previous design). Fuel tank connected to the engine bypassing the filter components of primary and secondary filter then the engine. Figure 2. 2 below shows about sketch placement of Fuel Tank on MV. Gili Cat II. Fuel tank connected to the engine bypassing the filter components of primary and secondary filter then the engine. Fuel tank and engine components connected using flexible rubber hose. There are three lines from the tank to the intake of each outboard motor. Its consists of 4 sections of flexible hose: intake tank - connectors, connector - primary filter, primary filter - secondary filter, a secondary filter - the outboard motor.

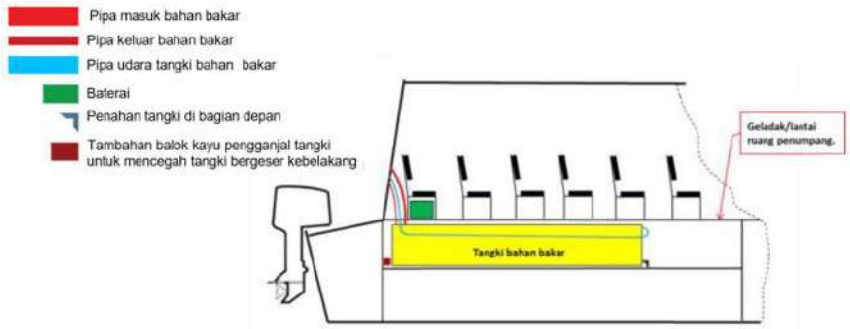



*Figure 2. 2 Sketch placement of Fuel Tank* [2]

[2] MV. Gili Cat II NTSC Draft Report, 2016

Three ship propulsion units (outboard engines) coupled in series. Control unit installed at the front of the cabin ship that becomes one with the passenger cabin. Pair cables are installed through long pipe that stretched under the boat deck from control room to stern of the ship. To navigate, Shipmaster aided by one GPS unit permanently installed on ships and 1 VHF radio unit is available to communicate.

MV. Gili Cat II has many types of life saving equipment. In accordance with the safety of passenger ship certification No. PK.001/05/KSOP.Pbl-2016 and RE certificates – Inspection Certificate Fire Fighter Extinguisher No: 010/PMK-YS/II/BL-16, MV. Gili Cat II using lifesaving equipment. That lifesaving equipment are described on Table 2. 1.

*Table 2. 1 Lifesaving equipment of MV. Gili Cat II* [3]

| No | Equipment | Quantity | Volume / Capacity | Checked |
|---|---|---|---|---|
| 1 | Firefighting equipment type dry powder (Pressure) | 2 bottles | 6,0 kg | February 26th 2016 |
| 2 | Inflatable Life raft | 5 pieces | 48 people | February 25th 2017 |
| 3 | Lifebuoys | 2 pieces | 2 people | May 25th 2018 |
| 4 | Lifejackets | 45 pieces | 45 people | May 25th 2019 |

### 2.1.2 Accident Chronology

MV. Gili Cat II had been exploded on Thursday, September 15th, 2016. An accident occurred at 09.35 GMT+08:00(Greenwich Mean Time) near Padangbai Port, Bali. The chronology of the accidents of MV. Gili Cat II explained in Table 2. 2 below. In this explosion accidents, there were 2 passengers got fatalities, some passengers got injuries. Table 2. 3 explained about detail casualties from the accidents.

*Table 2. 2 Chronology of Explosion*[4]

| No. | Date | Time (GMT+08:00) | Condition |
|---|---|---|---|
| 1 | September 14th, 2016 | 14:00 | 670 L Fuel was filled in Padangbai Port, Bali |

[3] MV. Gili Cat II NTSC Draft Report, 2016
[4] MV. Gili Cat II NTSC Draft Report, 2016

| No. | Date | Time (GMT+08:00) | Condition |
|---|---|---|---|
| 2 | September 15th, 2016 | 08:05 | Captain and 3 crews checked the condition of ships. |
| 3 | September 15th, 2016 | 08:20 | Captain check navigation tools, safety equipment and documents. |
| 4 | September15th, 2016 | 08:30 | Captain requested permission to lean on Pier 3 Port Padangbai. |
| 5 | September15th, 2016 | 09:00 | Passengers began boarding the ship. (35 Passengers) |
| 6 | September15th, 2016 | 09:25 | The ship departed to the port of Gili Trawangan, Lombok. |
| 7 | September15th, 2016 | 09:35 | The engine rotation speed increased to 3500 rpm and the speed starts to rise. |
| | | | The sound of a loud explosion from the stern of the ship and there was white smoke for 30 seconds. |
| 8 | September15th, 2016 | 09:37 | Captain lowered speed to 0 knots, turn off the engine, then ask for help from nearby vessels. |
| 9 | September15th, 2016 | 09:40 | Coming four speedboats (KM. Wahan Gili Ocean 1, MV. Marina Srikandi, MV. Sondex 1 and MV. Mahi-mahi Dewata). |
| 10 | September15th, 2016 | 09:40 | MV. Mahi-mahi Dewata ask permission attached to the right side for the evacuation, but was rejected by the Captain of MV. Gili Cat II. |
| 11 | September15th, 2016 | 09:40 | Captain had decided to ask for help from MV. Sondex 1 to pull the vessel MV. Gili Cat II to Pier 3. |
| 12 | September15th, 2016 | 09:50 | MV. Gili Cat II arrived at the port of Padangbai. |

*Table 2. 3 Casualties Data of Accidents* [5]

| Casualties | Fatalities | Major Injuries | Minor Injuries | Safe | Total |
|---|---|---|---|---|---|
| **Ship crew** | - | - | 1 | 3 | 4 |
| **Passenger** | 2 | 6 | 7 | 20 | 35 |
| **Total** | 2 | 6 | 8 | 23 | 39 |

[5] MV. Gili Cat II NTSC Draft Report, 2016

Note:

- 1-person fatalities when an explosion. According to witnesses, the passenger fatalities due to collide with the roof of the accommodation space when the explosion occurred.
- 1-person fatalities while being taken to hospital

## 2.2 Fire Process

### 2.2.1 Fire Theory

Fire is as oxidation event where the convergence of air, and the heat may result causing property damage or human injury or even death, (NFPA 30, 1992). Fire also can generally be interpreted as an uncontrolled event unbreak of fire which could endanger the safety of lives and property (DKI, 2008). Fire is the rapid oxidation of the material in the chemical process of combustion. It produces heat, light, and various other chemical reaction results. Fire formed from a chemical reaction (oxidation) which is composed of three elements, those are: heat, fuel, and air. It forming the flame commonly called the fire triangle. Figure 2. 3 explained about materials to forming a Fire / explosions.

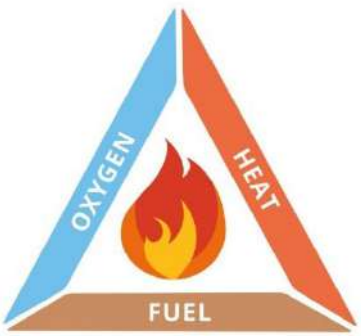



*Figure 2. 3 Fire Triangle (Spruce, 2016)*

If there is any one of those elements does not exist or are not on balance is sufficient, so Fire will not be formed. Fire triangle principle can be used as a basic for fire protection and fire prevention. When all three elements forming the Fire so the fire will not happen immediately, but only in the form of incandescence. For the formation of a fire there must be an element / support component, that is a chain of chemical reactions *(chemical chain reaction)*. The theory commonly known as fire pyramid *(fire tetrahedron)*. This theory is illustrated in Figure 2. 4 Early discovery of the *fire tetrahedron* theory originated from research and development of fire ectinguisher materials. Those materials are *dry chemical* fire extinguisher (chemical flour) and halons *(halon*

*hydrocarbon)*. The extinguisher types can break the chain reaction of the fire process continuity.

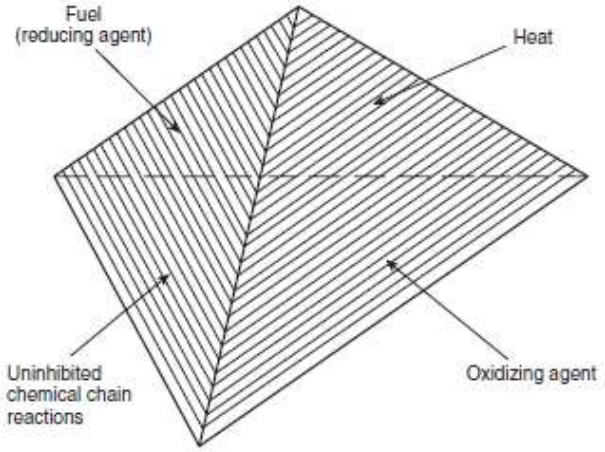



*Figure 2. 4 Fire Tetrahedron (NFPA 921, 2004)*

Chemical chain reaction is an event where there are three elements that react chemically with each other, thus resulting not only incandescent, but the form of flame or combustion events.

### 2.2.2 Fire Classification

Fire classification is an important thing to do. It can prevent of Fire or extinguish Fire. Classification of Fire can be distinguished base on sources that cause a fire. This classification is expected election of fire extinguisher according to the type of fire. So the Fire can be extinguished effectively and in accordance with established procedures.

#### 2.2.2.1 General Fire Classification

Fire classified according to the regulation (PerMen, 1980) classified fire into 4 categories namely A, B, C, D. While (NFPA 30, 1992) establishes five categories of types cause of the fire, that is class A, B, C, D and K. In fact, several countries assign additional classification with the class E.

The classification is as follows:

1. Class A
   Fire involving solid objects except metal. Example: Fire wood, paper, cloth, plastic, etc. Extinguish Fire of this class are using: sand, soil / sludge, powder extinguishers, foam and water.

2. Class B
   Fire that caused by a flammable liquids or gases. Example: Kerosene, diesel, gasoline, LPG / LNG, cooking oil. Extinguishers that can be used are: dry powder, foam, water in the form of spray / mist.
3. Class C
   Fire that caused by a voltage of electrical installation. Example: electrical Breaker and other household appliance that uses electricity. Extinguisher that can be used are: carbon dioxide ($CO_2$), dry powder. In this extinction are prohibited from using water.
4. Class D
   Fire on solid metal objects such as: magnesium, aluminum, sodium, potassium, etc. Extinguisher that can be used are: smooth or dry sand, special dry powder.
5. Class K
   Fire caused by the material due to the high concentration of grease. Fire of this type occur in the kitchen. Fire arising in the kitchen can be categorized in fire class B.
6. Class E
   Fire caused by short circuit of the electronic equipment. Extinguisher that can be used are: dry powder, but has a risk of damage to electronic equipment. Because dry powder has sticky properties. More appropriate to use the fire extinguisher made from clean agent. Clean agent has any benefit like extinguish fire fast, effectively, safe, and environmentally friendly.

#### 2.2.3.2 Flammable Liquid

The cause of the fire on the ship mostly from the engine room. In the engine room is easy to find of any flammable liquids. Flammable liquids are classified into several types, according to:

1. Flammable liquid with a flashpoint below 100° F
   Flammable liquid with a flashpoint below 100° F can be divided into several classes. This classes explained in Table 2. 4, as follows:

*Table 2. 4 Flammable liquid with a flashpoint below 100° F (NFPA 30, 1992)*

| Class | Flashpoint | Examples |
|---|---|---|
| Class II | > 100° F and <140° F | Diesel fuel, fuel oil, kerosene, motor oil |

| Class | Flashpoint | Examples |
|---|---|---|
| Class IIIA | > 140° F and <200° F | Furfural, linseed oil, mineral oil, oil-based paints |
| Class IIIB | > 200° F | Ethylene glycol, glycerin, neatsfoot oil |

2. Flammable liquid with a flashpoint above 100° F
   Flammable liquid with a flashpoint above 100° F can be divided into several classes. This classes explained in Table 2. 5, as follows:

*Table 2. 5 Flammable liquid with a flashpoint above 100° F (NFPA 30, 1992)*

| Class | Flashpoint | Boiling Point | Examples |
|---|---|---|---|
| Class IA | <73° F | <100° F | Ethyl ether, heptane, pentane, propylene oxide, vinyl chloride |
| Class IB | <73° F | > 100° F | Acetone, ethanol, gasoline, isopropyl alcohol, methanol, methyl ethyl ketone, octane, toluene |
| Class IC | > 73° F and <100° F | All boiling points | Isobutyl alcohol, mineral spirits, styrene monomer, turpentine, xylene |

### 2.2.3 Fire stages

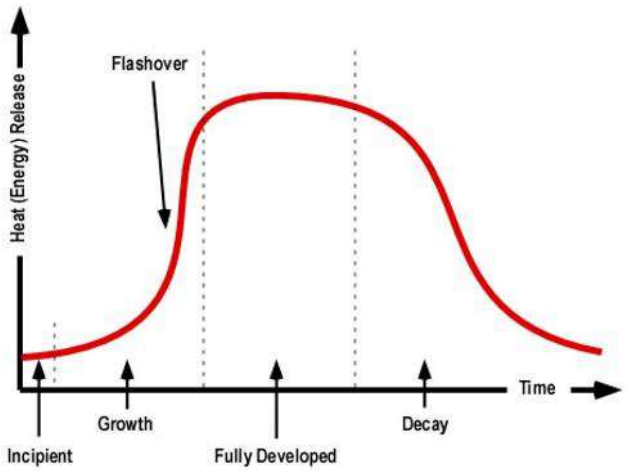



*Figure 2. 5 Stages of Fire (Hartin, 2007)*

Basically, a fire can be formed by three elements, those are oxygen, heat, and fuels (combustible materials). The Fire can be divided into several stages, those are: the stages of fire appear, the fire grew, the peak fire, and the fire outages. Figure 2. 5 below illustrates the stages of a fire starting a fire appear until the fire extinguished:

The following is an explanation of each of the stages of fire:

1. Stage Fire Appears
   Stage of fire appeared is an early stage of the fire. This stage begins with a chemical reaction between the three elements forming the fire are heat, oxygen, and combustible materials. At this stage, fire can easily be extinguished and even fire can be extinguished by itself when the fire cannot reach the next stage of Fire (elements forming the fire diminished, etc.). At this stage, suppression or escape can be determined.

2. Stage Fire Grows
   Growth can occur if the fire extinguishing measures are not carried out immediately or have not done at all. This stage can be recognized by combustible materials started to burn so heat (temperature) increases. When combustible materials are burned. It causes flashover (other combustible materials are combusted also due to the high heat). If there are people around the fire area, it could potentially lead victims are trapped, injured or even death.

3. Stage Peak Fire
   Fire peak occurs when all combustible materials ignite a whole so that the temperature of the fire reached its peak. Temperatures are so high that at this stage would be very dangerous for anyone trapped inside.

4. Stage of fire outages
   Fire outages stage is the stage of Fire that take the longest duration among the other stages. Levels of forming a fire like $O_2$ (oxygen) and the flammable material has begun to decline. However, if there are combustible materials unlit, it can immediately surround the fire could potentially cause a new flame. This stage is also the potential to cause a backdraft, which is an explosion that occurs due to oxygen supply suddenly. This can happen if a fire enclosed space suddenly

opened when the fire took place, so the fire more difficult to extinguish.

### 2.2.4 Explosion

An explosion is a rapid increase in volume and release of energy. Release of energy in extreme manner are usually with the generation of high temperatures and the releases of gas. Explosion is the sudden conversion of potential energy (chemical or mechanical) into kinetic energy. It product and release of gas under pressure. These high-pressure gases then do mechanical work, such as moving, changing, or shattering nearby materials. (NFPA 921, 2004)

There are two major types of explosions with which investigators are routinely involved: mechanical and chemical. The difference between those types are the source or mechanism by which the explosive pressures are produced. Mechanical explosions are explosions with high-pressure. Mechanical explosions produce gas a purely physical reaction. A purely mechanical explosion release of the stored high-pressure gas, such as compressed air, carbon dioxide, or oxygen. Bleves are sub-type of mechanical explosion. Bleves is the most common type explosion happen. It is type of mechanical explosion that will be encountered most frequently by the fire investigator. Figure 2. 6 is one example of bleves.

*Figure 2. 6 Bleves (TechnoKontrol, 2017)*

Chemical explosion can involve solid combustibles or explosive mixtures of fuel and oxidizer. More common to the fire investigator will be the propagating reactions involving gases, vapors, or dusts mixed with air. Combustion explosion is the most common of the chemical explosions.

Combustion explosion caused by the burning of combustible hydrocarbon fuels.

Before a fire or explosion can occur, three conditions must be met simultaneously. A fuel (combustible gas) and oxygen (air) must exist in certain proportions. It along with an ignition source, such as a spark or flame. The ratio of fuel and oxygen that is required varies with each combustible gas or vapor. The minimum concentration of a combustible gas or vapor necessary to support its combustion in air. It is defined as the Lower Explosive Limit (LEL) for that gas. Below this level, the mixture is too "lean" to burn. The maximum concentration of a gas or vapor that will burn in air is defined as the Upper Explosive Limit (UEL). Above this level, the mixture is too "rich" to burn. The range between the LEL and UEL is known as the flammable range for that gas or vapor. Figure 2. 7 explained the detail data of UEL and LFL of gasoline.


*Figure 2. 7 LFL and UEL List of gasoline* [6]

Accidents of MV. Gili Cat II caused an explosion of fuel oil system. This fuel oil system is using a gasoline. We can see that the LEL and UEL for gasoline are 1.4% and 7.6%. From the data above, if the capacity of fuel tank of MV. Gili Cat II is 1500 l. Explosion can happen only if the fuel has been vaporized within 21 – 114 liters.

## 2.3 Fire Prevention

Prevention as part of efforts to reduce the possibility of things that are not desirable. Similarly, fire prevention, it is intended to be operated ship feasible to operate and avoid the danger of fire. Thus, the regulations

[6] www.pertamina.com

concerning fire prevention made so that hazards cause of the fire can be avoided. The regulations on fire prevention in the ship listed to the (ILO, 1996). These regulations are as follows:

### 2.3.1 Smoke

- Smoking is only allowed in special places for smoking and instructions as well as warnings about the smoking ban should be put in places that are easily visible.
- Disposing of matchsticks and cigarette butts were still burning out of place is dangerous. Box cigarette butts must be provided and placed in a special place for smoking.
- The crew should be reminded of the dangers of smoking in the bedroom.

### 2.3.2 Electrical equipment and others

- People who do not have the authority is not allowed to handle the work associated premises electrical equipment and others.
- All electrical damage to the equipment, supplies, or power lines should be reported immediately to the electrician or the person responsible for handling electrical work.
- Each power line (circuit) which overload is not allowed because it can cause a fire.
- Portable heaters are not allowed to be used except in special circumstances and must be accompanied by a warning to users of the dangers that can be caused.
- Private portable heaters are not allowed to be used under any circumstances.
- All portable electrical equipment should be disconnected from the power line, if it is not used anymore.
- All electrical equipment belonging to private accommodation areas must use a plug of electricity corresponding to the plug hole (socket) that based on the standards.
- Power cable connection and plug holes branched (multi-socket plug) should not be used in residential spaces for connecting multiple electric equipment on the plug or socket.
- If the crew to use the equipment or portable lights, they must be able to ensure that the cables are through the door, hatches, manholes, etc., it should be protected and an insulation will not be damaged by the closing of the holes or closing the door, closing hatches (covers) or lids.

- The crew members are not allowed to install antennas (radio / television) adjacent to the ship radio antennas (vessels' s aerials)
- The crew did not permit to make improvements (unload) aircraft radio, compact disc player or other equipment without unplug the power plug, and before connecting the power cable again on the plug hole should be checked by an expert / electrician.
- Chart (Wall charts) which gives instructions on emergency first Life Saving to the crew that an electric shock (Suffered electrical shock) must be affixed in places where appropriate on the vessel, all crew must understand and be able to follow the procedures that have been listed on the chart / alerts.

### 2.3.3 Laundry and wet clothes

Cautious attitude should be done when drying clothes. Clothes should not be hung directly on or near the heater and not allowed to dry clothes in the engine room.

### 2.3.4 Flammable goods (*Spontaneous combustion*)

Garbage, cloth-rags and used goods (rubbish) such as clothes stained by paint, oil, and paint thinner, etc. are dangerous if left scattered because these items can cause fire by themselves (spontaneously combust). These items must be stored in bins that have been determined (proper dustbins) until these items can be disposed of safely.

### 2.3.5 Kitchen (*Galley*)

The kitchen has a fire hazard so fire blanket and fire extinguisher equipment must be available and ready to use. The use of water is not permittable in fire extinguish derived from cooking oil in the cooking area

## 2.4 Apollo Root Cause Analysis – RealityCharting

### 2.4.1 General Root Cause Analysis

Root Cause Analysis is a wide variety methods used to identify the causes of problems (tracing problem to their origin) and helps answer the question of why the problem happened in the first place, which in turn, and can helps us to prevent the recurrence. Many of the Root Cause Analysis methods can be utilize in basic problem solving, however they have received criticism for being too basic to analyze root causes to the depth that is needed to ensure that solutions are identified and the problem is solved.

Traditional root cause analysis (RCA) is used to retrace the chain of causes that led to event, so it can find the single cause that set everything else in motion, known as the "root cause". The basic theory if RCA is finding and eliminating the single root cause so it will solve the problem. But after years of investigation in nuclear field of 1979 Three Mile Island Nuclear Power Plant partial meltdown, Dean L. Gano realized that traditional RCA method were not working. Traditional RCA methods weakness are the problem solving were people-centric and subjective rather than principle-based and objective. There are some methods that used in traditional RCA methods such as Linear thinking, Categorization, Storytelling, and Common Sense. Then Dean L. Gano made seven steps to problem solving effectively. These seven steps are:

1. Define the problem.
2. Determine the known causal relationships to include the actions and conditions of each effect.
3. Provide a graphical representation of the causal relationships to include specific action and conditional causes.
4. Provide evidence to support the existence of each cause.
5. Determine if each set of causes is sufficient and necessary to cause the effect.
6. Provide effective solutions that remove, change, or control one or more causes of the event. Solutions must be shown to prevent recurrence, meet our goals and objectives, be within our control, and will not cause other problems.
7. Implement and track the effectiveness of each solution.

### 2.4.2 Apollo Root Cause Analysis – Reality Charting

Apollo Root Cause Analysis – RealityCharting is used in this thesis. ARCA is recommended for event / Incident-based items of complex and higher significance. There is some benefit of apollo root cause analysis – realitycharting:

1. Create a Common Reality: A RealityCharting is produced showing all the known causes and their inter-relationships. Because all stakeholders can see these causal relationships in the RealityCharting, buy-in of the solutions is readily attained.
2. Eliminated Recurring Problems: identifying solutions that are within the organization's control, prevent recurrence, and meet the organization's goals and objectives.

3. Get a Define Result: The result in clear causal connections between your solutions and the defined problem.
4. Address Any Size Problem: scalable to any problem, large or small.
5. Eliminate Assumption: The evidence requirement for each cause ensures that there is no "story telling" involved.

Comparison the Apollo RCA – RealityCharting with the other various methods or tool RCA in use today. Figure 2. 8 showed below is a result of comparison of RealityCharting methods and other RCA methods or tools.

| Method/Tool | Type | Defines Problem | Defines All Known Causes | Provides A Causal Path To Root Causes | Delineates Evidence | Explains How Solutions Prevent Recurrence | Easy To Follow Report | Score |
|---|---|---|---|---|---|---|---|---|
| Events & Causal Factors | Method | Yes | Limited | No | No | No | No | 1.5 |
| Change Analysis | Tool | Yes | No | No | No | No | No | 1 |
| Barrier Analysis | Tool | Yes | No | No | No | No | No | 1 |
| Tree Diagrams | Method | Yes | No | No | No | No | No | 1 |
| Why-Why Chart | Method | Yes | No | Yes | No | No | No | 2 |
| Pareto | Tool | Yes | No | No | No | No | No | 1 |
| Storytelling | Method | Limited | No | No | No | No | No | 0.5 |
| Fault Tree | Method | Yes | Yes | Yes | No | Yes | No | 4 |
| FMEA | Tool | Yes | No | Limited | No | Limited | No | 2 |
| **RealityCharting®** | **Method** | **Yes** | **Yes** | **Yes** | **Yes** | **Yes** | **Yes** | **6** |

*Figure 2. 8 Comparison of Selected RCA Methods and Tools (Gano, 2011)*

RealityCharting is a simple causal process whereby one asks why of a defined problem, answers with at least two causes in the form of an action and condition, then asks why of each answer and continues asking why of each stated cause until there are no more answers. The answer or causes is supported with evidence or use "?". A search for the unknown is launched and the process is repeated several times until the cause-and-effect chart, called RealityChart. It is created to show all the known causes and their interrelationships. All causes then examined to find a way to change them with a solution that is within your control, prevent recurrence, meets a goals and objectives, and does not cause other problems. The result is clear causal connections between your solutions and the defined problem then the solutions is readily attained. To complete the apollo root cause analysis, there are 4 steps that should followed. Four steps that should followed are:

1. Define the problem.

- What, When, and Where.
- Significant: Safety, Environmental, Cost, etc.
- Frequency of the problem.

2. Create chart (Reality or Cause-Effect Chart). Chart is created supported with evidence.
   - Iterative process.
   - Look for an appropriate end to each part.
3. Identify possible effective solution.
   - Brainstorm.
   - Not just the favorite solution.
4. Implement best solution and finalize the report.
   - Complete correction action.

But before it started to define the problem, it should gather information first. All the information like drawing, picture, evidence preservation, conduct interviewers, create timeline / sequence of events, etc.

A Realitychart or cause-effect chart is a process that we do after we define the problem. Cause-effect has a principle or we can say as 4 characteristics of cause-effect:

1. Cause & Effect are the same thing.
2. Each effect has at least two causes in the form of action & condition. Figure 2. 9 is an example of simple RealityCharting. The definition of action are causes that interact with conditions to cause an effect. Conditions are causes that exist in time prior to an action bringing them together to cause an effect.

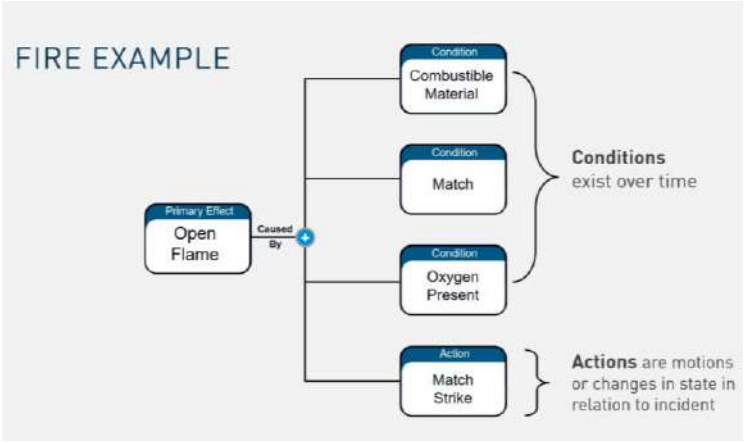



*Figure 2. 9 Reality Charting Simple Example (Gano, 2011)*

3. Causes & Effect are part of an infinite continuum of causes.
   - Causes: Like jigsaw puzzle (no edges).
   - More connection will make a better picture.
   - Each cause can be the beginning and the end.
   - More connection will make a bigger chart then give more opportunity to place more solutions.

4. An effect exists only if its causes exist in the same space and time frame.

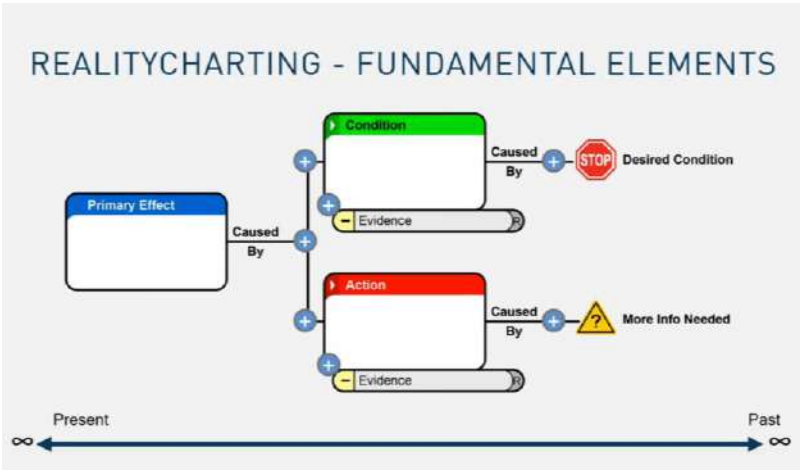



*Figure 2. 10 Reality Charting - Fundamental Elements (Gano, 2011)*

For making any reality charting we must follow some elements. Figure 2. 10 shown above is a fundamental element of realitycharting. These fundamental elements for reality charting are:

1. For each primary effect ask “why”
2. Look for cause in action and conditional.
3. Comment all causes with “caused by”.
4. Support all causes with evidence.
5. Each caused path with “?” or a reason for stopping.

There are four reasons for stopping in creating root cause analysis using RealityCharting.

1. *Desired Condition*: This is the most common reason for stopping. The event was pursuit one or more goals. If you reach your goal, there is no need to continue asking why. If your goal is faulty, that is another matter.
2. *Lack of Control: This reason is outside members or members organization control.*
3. *New Primary Effect: This reason is often used as an interim stopping point because you have a separate team working on the details of this cause. When they are done, you can easily import their Realitychart into the final analysis.*
4. *Other Cause Paths More Productive: After we recommend some solution but it cannot be implemented because it is not productive or cost is too high. So, it doesn’t make any sense to continue down there cause paths and spend more time and money when you already have effective solutions.*

There are some rules that used for every evidence in creating a RealityCharting. These rules for realitycharting evidence are:

- Applying evidence to the chart.
- Difficulties recognizing evidence.
- Rules for acceptable evidences are:
    - Sense evidence : sight, sound, taste, touch, and smell.
    - Inferred evidence :
        - Known by repeatable casual relationships.
        - Photos, videos, trendchart, logbook, lab sample, etc.
        - Inferred evidence should always be verified.

After we create any realitychart, the next process is identifying possible solutions. The possible solutions criteria that can accepted are:

1. Prevent recurrence.
2. Within your control.
3. Must appropriate with goal & objectives.
4. It would not make any new other problem.

There are 4 steps to make an effective solution. These are:

1. Challenge each cause by asking how we can remove, change or control it and offer solutions.
2. Do not restrict ideas – brainstorming.
3. Check each solution using criteria.
4. Implement the solutions that best pass the criteria.

How to make a solution for RealityCharting? These are the solution processes for RealityCharting:

- Challenge each cause & offer a solution.
    - Start in upper right-hand corner.
    - What can be done to remove, change, or control.
    - Brainstorming.
    - May have to revise chart.
    - Think outside the box.
- Identify best solution.
    - It must meet the solution criteria.
    - The best solution is often applied to conditional causes.

*"This page intentionally blank"*

# CHAPTER 3
# RESEARCH METHODOLOGY

## 3.1 General

The methodology is a step that must be done on an activity to achieve certain objectives, in this case is the thesis. In this thesis, writing a good methodology became one of the most important points. It is because in this methodology will explain what processes should be done, starts from the formulation explanation of the problem, the data what should have, then how the data is processed, until purpose of the thesis.

## 3.2 Methodology Flowchart

The stages are carried out in the writing of this thesis methodology will be described in the form of a flowchart. Flowchart shown in Figure 3. 1 and Figure 3. 2.

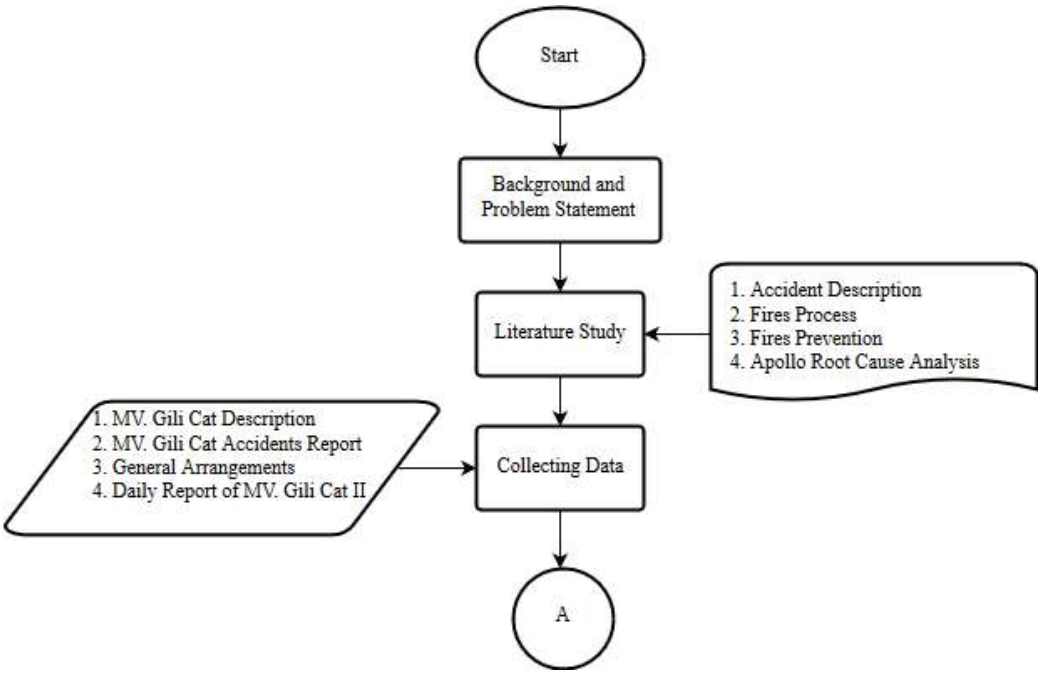



*Figure 3. 1 Methodology Flowchart*

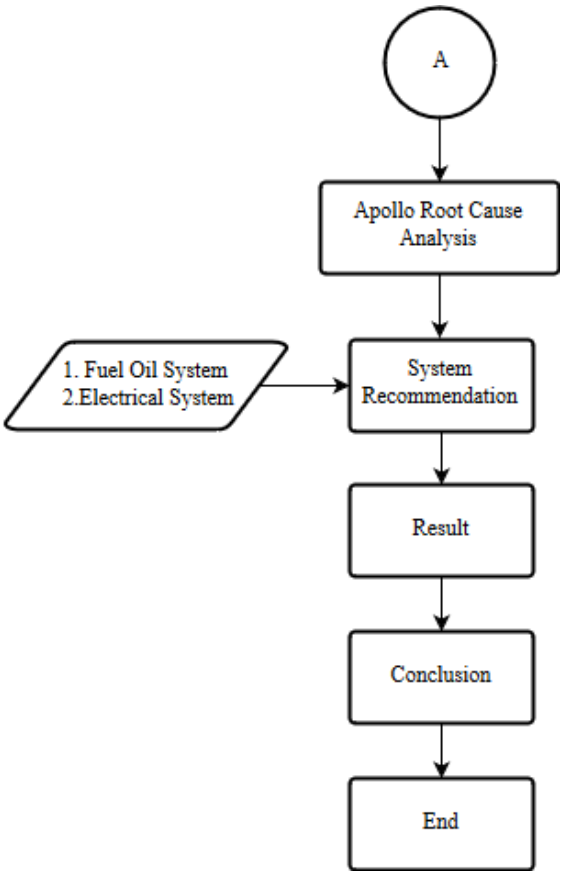



*Figure 3. 2 Methodology Flowchart Continue*

## 3.3 Background and Problem Statement

Identifying the problems is to determine what are the problem statements. Problem statement should be related with the case. This stage is very important cause we must know why these problems are worthy to be used as material in thesis.

In this phase, the background of writing and the problem statement will be described. The background of this thesis is that the accident MV. Gili Cat II and the high rate of Fire / explosions of all accidents aboard ships. Problem statement of this thesis are what is the root cause of this case and how to mitigate it. After problem statement is done, then we need to continue with collecting and understand literature study.

## 3.4 Literature Study

The Literature study is a stage that explain the basic theories that will be used in this thesis. Sources used in the writing of literature on this thesis comes from paper, books, standard and code, news, and another similar thesis.

In this thesis, there are some literature study need to collect and understand. Those literature study are MV. Gili Cat Accidents Description, Fire Process, Fire Prevention, and Apollo Root Cause Analysis Methods.
After all the literature study are collected and understood in detail, we can continue with data collecting. Data collecting should be related with the case and literature study also.

## 3.5 Collecting Data

Collecting Data are needed to complete the thesis. Collecting data is a critical point of this thesis, cause all data will support for writing this thesis. Collecting data in this thesis are coming from National Transportation Safety Committee (NTSC).

Collecting data that needed in this thesis are the description MV. Gili Cat II, MV. Gili Cat II accident reports, general arrangement, daily report of MV. Gili Cat II. Collecting data are needed to process of completing this thesis.

The description MV. Gili Cat II, MV. Gili Cat II accident reports are useful to create root cause analysis using Apollo root cause analysis methodology. Then, the description of MV. Gili Cat II, general arrangement, daily report of MV. Gili Cat II are needed to creating Fuel Oil System (FOS) and Electrical System.

## 3.6 Apollo Root Cause Analysis

The description of MV. Gili Cat II and MV. Gili Cat II accidents report will be an input to create a root cause analysis. Apollo Root Cause Analysis is a stage to determine main cause (root cause) of the accidents (Fire). Apollo root cause analysis will be assisted with realitycharting program.

There is some step to complete an Apollo Root Cause Analysis method. Those steps are: Define the problem, creating chart, identify possible solution, implement best solution, and finalize the report. Report in this thesis will be created automatically.

The first step of this methods is defining the problem. Define the problem is a step about detail description of the cases. Detail description are about what, when, where of the cases happened, what significant we concern about (safety, environmental, cost, etc.), and the frequency of the cases happen. The next stage is creating a realitychart. Create realitychart should be done in detail. Each cause of the cart should be supported with evidence. Evidence of the causes could be coming from sense evidence (sight, sound, taste, touch, and smell) or inferred evidence (photos, videos, trendchart, logbook, etc.)

The third step is identifying possible solution. Possible solutions criteria that can be accepted are prevent recurrence, must appropriate with objectives, it would not make any new other problem. After that, implement best solution. Implementing solution should be assessed. Solution assessment of MV. Gili Cat II is done by giving a questionnaire to the expert (NTSC). After all the step, the last one is creating report. Report of the cases will be done automatically by realitycharting program.

The results of this analysis are: what are the root cause of this problem, what are possible solution that can be implemented, and how is the report of the analysis.

## 3.7 System Recommendation

The description of MV. Gili Cat II, general arrangement, daily report of MV. Gili Cat II are needed to support of system recommendation. Recommendation in this thesis is related to condition that are not following based on standard (NCSV Chapter V - Machinery & Electrical) especially on fuel oil system and electrical system.

Recommendation of fuel oil system and electrical system are action to prevent explosion of MV. Gili Cat II. System recommendation of this thesis is according to NCVS (Non-Conventional Vessel Standard) and NFPA. After FOS and Electrical system recommendation already completed, it can use for preventing similar case or it can be used for other parties.

## 3.8 Conclusion

This phase is a summary of this thesis, as a result of this thesis and what can be learned from this thesis. The final step is to make the conclusion that

the whole process has been done before as well as provide answers to existing problems.

This phase is an act or suggestions are being made to reduce the possibility of similar dangers. Mitigation suggestion is a solution to prevent recurrence of similar accidents. Conclusion and recommendation from this thesis are what are the root cause of the problem, what are the implemented solution, how is the design of fuel oil system and electrical system according to NCVS.

*"This page intentionally blank"*

# CHAPTER 4
# DISCUSSION AND DATA ANALYSIS

## 4.1 General

In the data analysis and discussion, there are several steps that need to be explained. Steps that need to be explained are about the methods of Apollo Root Cause Analysis (ARCA). Then it will continue with the design process of the fuel system and the electrical system on the ship. The data required to support the work of this thesis include the MV. Gili Cat II Description, MV. Gili Cat II Accidents Report, General Arrangements, and Daily Report of MV. Gili Cat II.

An initial stage is to identify documents that have been obtained. Those documents are MV. Gili Cat II Description, MV. Gili Cat II Accidents Report, General Arrangements, and Daily Report of MV. Gili Cat II. That information can be used as evidence relating to the explosion MV. Gili Cat II.

The next stage is to process the data that has obtained. Data will be processed using Apollo Root Cause Analysis (ARCA) methods. RealityCharting application usage is to support the Apollo Root Cause Analysis method. In ARCA methods, there are several steps that need to be done. The following stages include: define the problem, create chart, identify possible effective solution, implement the best solution, finalize the report.

In the first stage of doing that ARCA method Define the problemis to explain events (accidents) are as detailed as possible. Then proceed with the Create Chart. Creating chart are made must be included with the evidence that already exists. After creating chart is complete, then proceed with the Identify possible solution. At this stage, any solution will be identified should be related to the case being dealt with. There are some criterias in identifying possible solution. These criteria are given solution must prevent recurrence of the problem, within your control, must appropriate with goals and objectives, and it will not make any other / new problem. After identifying of possible solution has been completed then followed by implementing those solutions. Implement

best solution can be done through assessment solution. Assessment solution was performed to assess any solution that can be implemented in a related case. After finished assessing any solution that can be implemented, then continue with the finalized report. Finalize the report is the creation of a report on the results, which has been obtained at each stage.

## 4.2 Data collection

In this section will be discussed on the analysis of data obtained previously. This data is used to support root cause analysis process. This collected data is useful in Apollo Root Cause Analysis methods to define the problem, creating charts and provide evidence on each chart. Here are the data that has been collected:

### 4.2.1 MV. Gili Cat II Description

MV. Gili Cat II Description is a general data about the ship. General data such as ship particular, ship propulsion systems, machinery and fuel systems, data about the crew, passenger load information, and safety equipments.

- The main data of ship: MV. Gili Cat II is a passenger ship that serves from Padangbai (Bali) - Gili Trawangan (Lombok). The ship was built in 2001 in Australia. This ship is made of aluminum. MV. Gili Cat II have general data as follows:
  - Overall Length : 11.69 m
  - Breadth Molded : 3.42 m
  - Draft : 0.60 m
  - Depth : 0.90 m
  - Gross Tonnage : 6 T
  - Net Tonnage : -
  - Type : Passenger Ship
  - Flag : Indonesia
  - Production Year : 2001
  - Production Location : Australia
  - Construction Materials : Aluminum

- Ship Propulsion Systems
  Ship steering system consists of two wires that connect to the mechanical system of the outboard motor propeller. This ship propulsion motor has 3 units and installed in series. Ship machinery control is on the console mounted on the front of a ship's cabin. Pair cable of ship steering are installed through a long pipe that cross on under the deck of the ship. Navigation MV. Gili Cat II conducted by a captain assisted by 1 GPS units that are permanently installed and 1 unit VHF radio to communicate.

- Machinery and Fuel Systems
  Motors that used on this ship are 3 units of Suzuki DF300 four-stroke type . One unit of outboard motors has power of 300 HP. Configuring the ship's engine at maximum rotation can provide power until speeds in 45 knots. However, these motors are operated at an average speed in 20-25 knots. At this speeds, the ship can travel between Padangbai - Gili Trawangan within 1.5 hours. Figure 4. 1 is an overview of the steering and control engine console from MV. Gili Cat II.

*Figure 4. 1 Steering and Control Engine Console* [1]

Fuel used on this engine is gasoline. But in the last 3 months, MV. Gili Cat II uses a fuel mixture of gasoline and pertalite. The fuel is

[1] MV. Gili Cat II NTSC Draft Report, 2016

stored in tanks that are on the lower deck with a capacity of 1500 liters. As for filling the fuel tank carried by the crew manually.

- Crew Data
  At the time of the explosion of the ship, the MV. Gili Cat manned by four crews. The crew consists of a Captain (skipper), Chief Engineer, and 2 sailors. The crew certifications can be seen on Table 4. 1, as follows:

*Table 4. 1 Crew Data of MV. Gili Cat II*[2]

| No. | Ship's crew | Diploma / Certificate | Date released | SEA (Seafarer's Employment Agreement) |
|---|---|---|---|---|
| **1** | Captain | ANT-IV | March 07th, 2013 | PT. Wallacea Jalesveva Lestari (03/04/2016) |
| | | BST | May 27th, 2015 | |
| | | SCRB | November 22nd, 2011 | |
| | | AFF | November 29th, 2011 | |
| | | MC | November 30th, 2011 | |
| | | MEFA | November 16th, 2011 | |
| | | ISM CODE | September 24th, 2012 | |
| | | SAT | February 10th, 2015 | |
| **2** | Chief Engineer | ATT-V | September 11th, 2012 | - (06/25/2013) |
| | | BST | May 22nd, 2015 | |
| | | AFF | May 13rd, 2015 | |
| | | SAT RFPWER | August24th, 2015 | |

[2] MV. Gili Cat II NTSC Draft Report, 2016

| No. | Ship's crew | Diploma / Certificate | Date released | SEA (Seafarer's Employment Agreement) |
|---|---|---|---|---|
| **3** | Sailor I | BST | January 04th, 2014 | PT. INDONUSA SEGARA MARINE (05/01/2014) |
| **4** | Sailor II | BST | February 29th, 2016 | PT. Wallacea Jalesveva Lestari (03/04/2016 |

- Cargo (Passenger) Information
  The number of passengers on MV. Gili Cat II has 39 people consisting of 35 passengers and 4 crews. 35 passengers are foreign tourists from United Kingdom (UK), France, Germany, Austria, Netherlands, Switzerland, Spain, Italy, Ireland, and Portugal.

- Safety Equipments
  MV. Gili Cat II has been equipped with a variety of safety equipment. In accordance with the Passenger Ship Safety Certificate No. PK.001 / 05 / KSOP.Pbl-2016 and RE certificates - Fighter Fire Extinguisher Inspection Certificate No: 010 / PMK-YS / II / BL-16, MV. Gili Cat II equipped with safety equipment described in Table 4. 2 following.

*Table 4. 2 MV. Gili Cat II Safety Equipment* [3]

| No. | Types | Amount | Volume / Capacity | Tested |
|---|---|---|---|---|
| **1** | Powder extinguisher types (Pressure | 2 tube | 6.0 kg | February 26th, 2016 |
| **2** | Life raft bloating (Inflatable Liferaft) | 5 pieces | 48 people | February 25 th, 2016 |

[3] MV. Gili Cat II NTSC Draft Report, 2016

| No. | Types | Amount | Volume / Capacity | Tested |
|---|---|---|---|---|
| **3** | The buoy helper (lifebuoys) | 2 pieces | 2 persons | May 25 th, 2016 |
| **4** | Jackets helper (lifejackets) | 45 pieces | 45 people | May 25 th, 2016 |

### 4.2.2 MV. Gili Cat II Accidents Report

MV. Gili Cat II exploded on Thursday, September 15th, 2016. The MV. Gili Cat II was departed from Padangbai, Bali to Gili Trawangan, Lombok. An accident occurred at 09:35 near of Padangbai Port, Bali. There were 35 passengers onboard when the ship exploded. MV. Sondex 1 MV help. Gili Cat II to pull the vessel to Pier 3 Padangbai Port. In this accident, there were two passengers got fatalities. The detailed chronology of MV.Gili Cat II explosion has been described in Chapter II.1.

### 4.2.3 General Arrangements

General Arrangement is a general design of entire compartments of the ship. In general arrangements, it is figuring about ships design seen from a top view and side view. It is easier for users to be able to calculate the actual vessel dimension in accordance with the scale of the images used. The General Arrangement on this ship is Figure 4. 2, as follows.

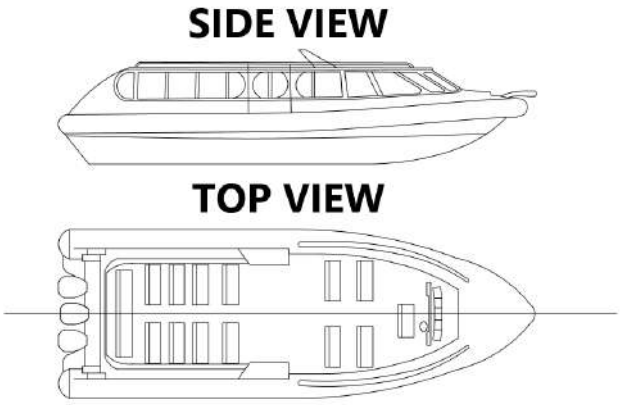



*Figure 4. 2 MV. Gili Cat II General Arrangements* [4]

[4] MV. Gili Cat II NTSC Draft Report, 2016

### 4.2.4 Daily Report of MV. Gili Cat II.

Daily Report on MV. Gili Cat II is an important document containing the that can be trusted with a record considered carefully and meticulously arranged, each event is recorded.

## 4.3 Apollo Root Cause Analysis

After analyzing and identificate the data that has been obtained, the next step is to evaluate the occurrence of an explosion on the vessel MV. Gili Cat II. Aim of evaluation is to find out what are the root cause of the explosion. In ARCA method, there are 5 steps that must be followed, those are: Define Problem, Create Chart, Effective Solution Possible Identify, Implement Best Solution, Finalize the report.

### 4.3.1 Define the problem

Define the problem is the first step in Apollo Root Cause Analysis methods. At this stage, every detail of the problems will be explained, who will analyze the problem, an important note in the problem, the source of the data (reference), etc. Details explained at this stage will be divided into five stages. These stages include: problem definiton, team members, notes, references, and rules check. Problem definition will explain "what is the problem", when (date, time) the problem happens, where (location), significance (safety, environment, cost, etc). In this case, the problem of definition of RealityCharting application are explained in Appendix 1.

Problem Definition in this case is:

| | |
|---|---|
| What | : Ship Accident (Explosion) – MV. Gili Cat II |
| When | : - |
| Date | : September 15th, 2016 |
| Time | : 09:30 GMT+08:00 |
| Where | : Bali |
| Location | : Padangbai Port, Bali |
| Significance | : - |
| Safety | : Fire / Explosion |
| Environment | : - |
| Revenue | : - |
| Cost | : - |

Frequency : 1

Then proceed to fill in the information about team members. Team members are those who would analyze the problems proficiency level. The information to be filled include name, email, and personal information is require. Appendix 1 will explain how your team members on a charging visualization RealityCharting application.

Team members in this case is:

- Ricard Diago Sambuaga : College Student
- Dr. Eng. Trika Pitana, ST., M.Sc. : 1st Supervisor
- Ir. Dwi Priyanta, M.SE. : 2nd Supervisor
- Aleik Nurwahyudy : NCVS Investigator

The next stage is to fill important notes of this case. After fill an important notes, so next step was filling reference. This reference contains any data sources that we use to supporting this process of root cause analysis. On Appendix 1 will explain about visualization to fill a RealityCharting reference on the application. As you create your chart, the software automatically Identifies the which causes are affected by the rule violations and will probably need further work. These are quickly intervening Viewed by selecting the Rule Violations cause attribute, located on the workspace above the cause of headings.

There are some references that author used in this thesis. References that used in this thesis are:

- NTSC MV. Gili Cat II Draft Report
- Dean L. Gano. RealityCharting – Seven steps to Effective Problem Solving and Strategies for Personal Success
- NFPA (National Fire Protection Association) 921
- NCVS (Non-Conventional Vessel Standard) Chapter V

The Rules Check window Provides a place to monitor seven chart of construction rules, identify individual violations for each offending cause, initiate or bypass the rules check and select an advanced rule checking to perform.

1. The "Empty Cause" rule checks the cause Realitychart for any empty boxes.
2. The "unconnected Cause" rule checks the Realitychart for any unconnected causes.
3. The "Action / Condition Type" rule checks to the make sure all causes have been identified as an action or condition cause.
4. The "Action-Condition Requirement" rule checks to the make sure the effect every action has at least one cause and one cause condition.
5. The "Conjunction" Identifies any rule conjunctions to help Ensure causes Contain only one noun-verb statements and are not telling a story.
6. The "Evidence" rule checks to the make sure every cause has evidence to support it.
7. The "Point of Ignorance" rule checks to the make sure the all cause paths have a defined ending.

Appendix 1 will explain how your visualization of RealityCharting rules check on the application, as follows. After rules check process has been completed and every rules check status has passed so all define problem stages has been completed. It will proceed with the next step which is to the create chart.

### 4.3.2 Create Chart

Create chart is the second step in performing of apollo root cause analysis method. There is an important things in creating chart of ARCA methods. Each chart should be supported by an evidence. Creating charts in ARCA method has several rules, as follows:

1. Cause and effect are the same thing.
2. Each effect has at least two causes in the form of action and condition. Figure II. 8 is an example of simple RealityCharting.
3. Causes & Effects are part of an infinite continuum of causes.
4. An effect exists only if its causes exist in the same space and time frame.

In the first stage is to choose a top event / primary effect. Primary Effect is a major failure that occurs in an event. MV. Gili Cat II explosion accident selected as the top event / primary effect.

In the second stage followed by determining the cause of the effect. Create charts in ARCA methods have some fundamental elements. Fundamental elements include: For each primary effect ask "why", cause is created consisting of condition and action, comment all causes with "the caused by", support all causes with evidence, and each caused path with "?" Or a reason for stopping. Numbering of each chart is useful for reading the chart. Appendix 1 will describe about numbering of each chart in this case.

MV. Gili Cat II explosion location is in below of the deck. Location of the explosion is beside of the fuel tank. Explosion can happen caused by saturated gas are accumulated in that below deck. After saturated gas accumulated, then there is mixing between air (oxygen) and saturated gas (Fuel) and an Igniter. Because of these three elements so explosion can happen. Figure 4. 3 is described location of the explosion and the layout of the ship. The discussion of this case is described in Figure 4. 4.

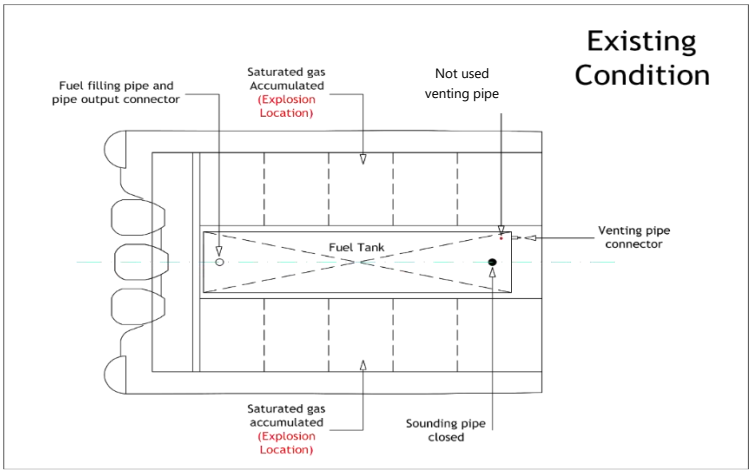



*Figure 4. 3 Detail Location of the Explosion*[5]

[5] MV. Gili Cat II NTSC Draft Report, 2016

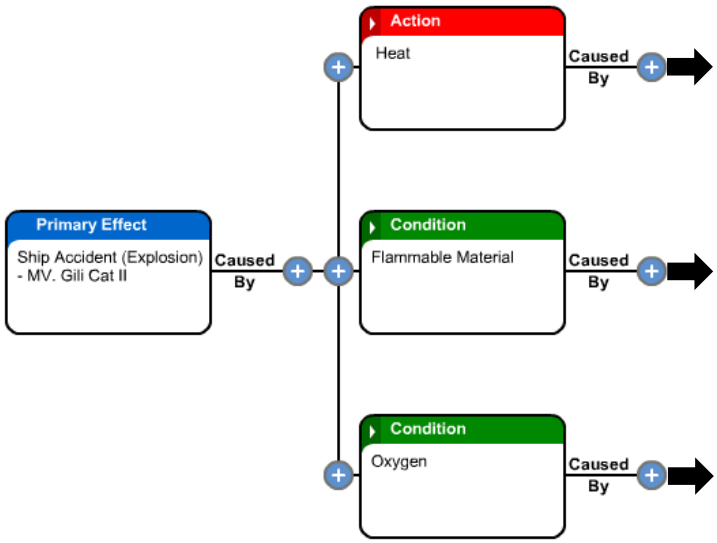



*Figure 4. 4 Chart (Explosion MV. Gili Cat) part 1* [6]

1.0 Why the Ship Accidents (Explosion) - MV. Gili Cat II can happen?
1.1 (A) Heat
1.2 (C) Flammable Material
1.3 (C) Oxygen

In the third stage is continued on Figure 4. 5 given the question why 1.1 (A) Heat in the second stage can happen. The answer of this question are as follows:

1.1 Why Heat can happen?
1.1.1 (A) Static electrical around of the tank and hull
1.1.2 (C) Bad electrical wiring system

[6] RealityCharting

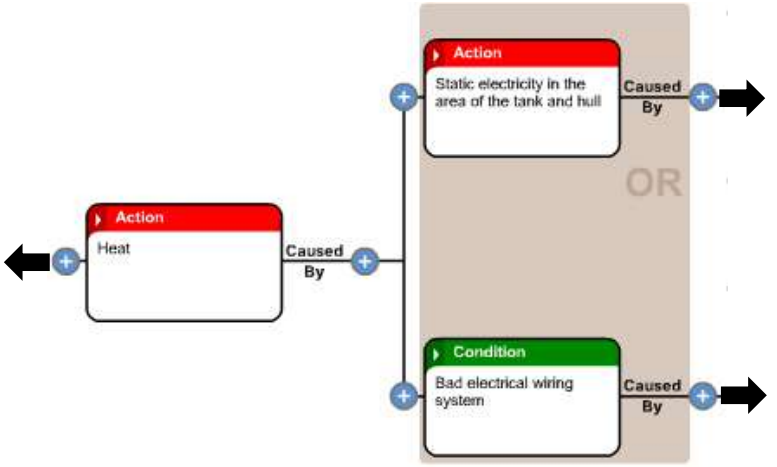



*Figure 4. 5 Chart (Explosion MV. Gili Cat) part 2* [7]

In the fourth stage is continued on Figure 4. 6 and Figure 4. 11 given the question why on every answer in the third stage. Figure 4. 12 is the causes of Figure 4. 11. The answer of each question is as follows:

1.1.1 Why are there a static electricity in the area of the tank and hull?

1.1.1.1 (C) There is no earthing system (grounding) – STOP (More Info Needed)

1.1.1.2 (A) oxygen result dust particles being attracted to the rubbed surfaced – STOP (More Info Needed)

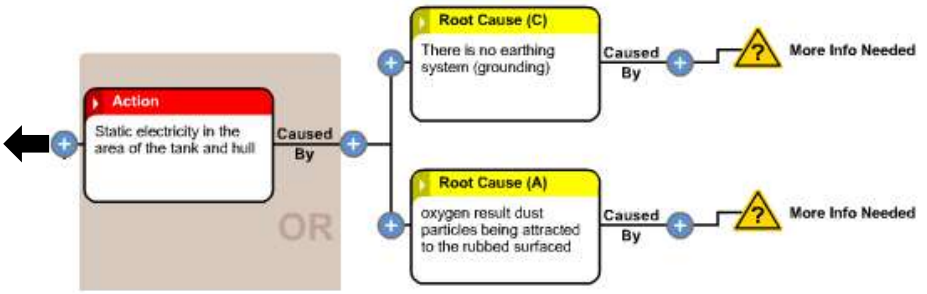



*Figure 4. 6 Chart (Explosion MV. Gili Cat) part 3* [8]

[7] RealityCharting
[8] RealityCharting

There are evidences for each cause. Those evidences for tightening battery using belt tied manually and wood boards and sponges used as a prop for battery are described in Figure 4. 7 and Figure 4. 8.

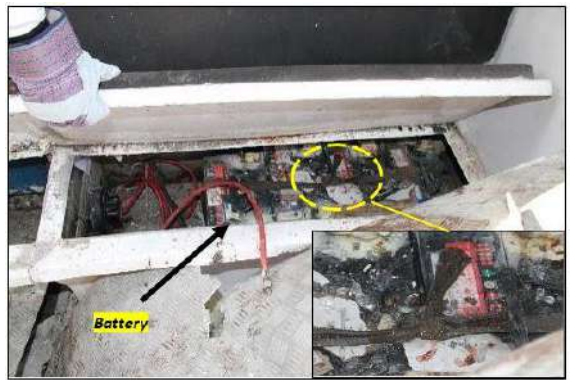



*Figure 4. 7 Evidence for Tightening Battery Manually*[9]

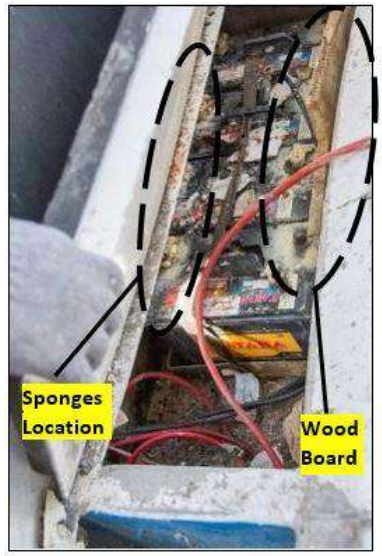



*Figure 4. 8 Evidence for Wood boards and sponges used as a prop for battery*[10]

Evidence for switch & contact pole are not protected with isolator, battery spaces is not in a good condition, and there is a gap between battery spaces described in Figure 4. 9 and Figure 4. 10.

[9] NTSC Investigation
[10] NTSC Investigation

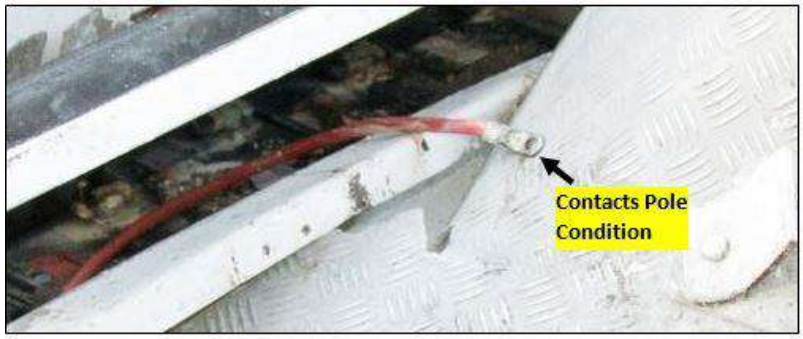



*Figure 4. 9 Evidence for contacts pole condition (without isolator)*[11]

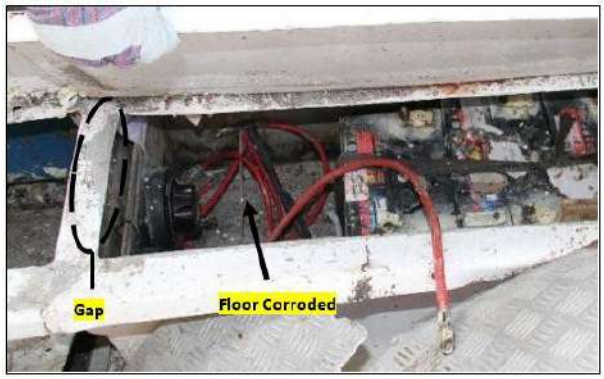



*Figure 4. 10 Evidence for battery spaces is not in good condition*[12]

1.1.1 Why are there a bad electrical wiring system?

1.1.1.1 (A) Ship crews did not check well – STOP (Lack of Control)

1.1.1.2 (A) Ship crews did not check regularly – STOP (Lack of Control)

1.1.1.3 (C) Battery compartment is not in good condition

1.1.1.4 (C) Switch and contacts pole are not protected with isolator – STOP (Lack of Control)

1.1.1.5 (C) Broken Socket – STOP (Lack of Control)

[11] NTSC Investigation
[12] NTSC Investigation

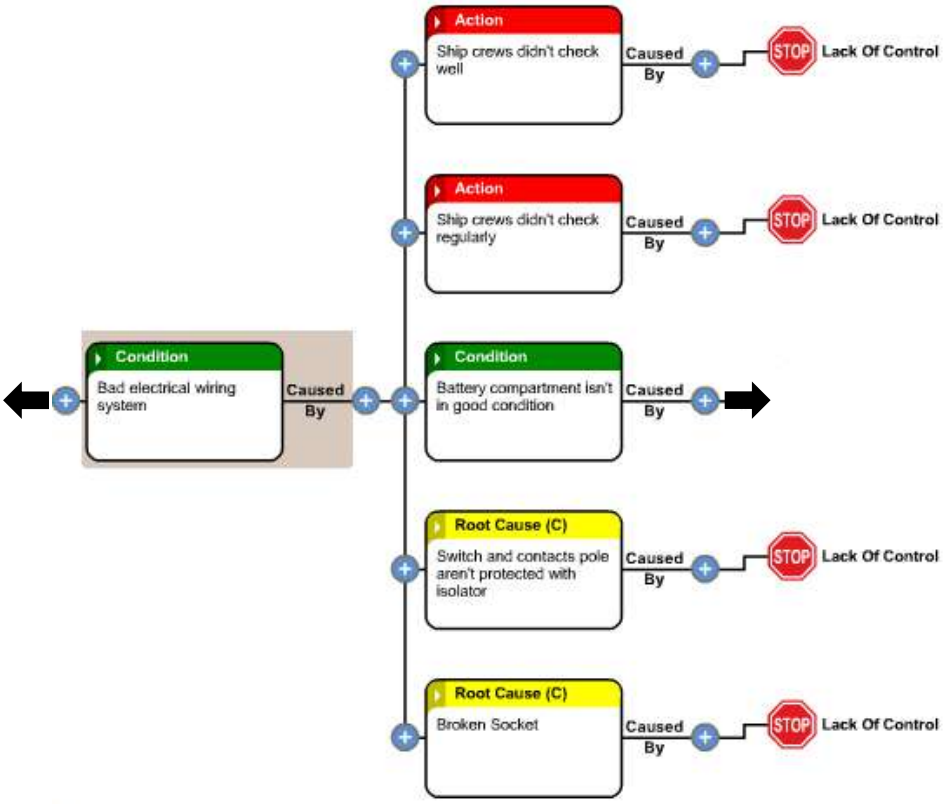



*Figure 4. 11 Chart (Explosion MV. Gili Cat) part 4* [13]

1.1.1.1 Why battery compartment is not in good condition?

1.1.1.1.1 (A) Ship crews tightening battery using belt tied manually – STOP (Desired Condition)

1.1.1.1.2 (C) There is a gap between battery spaces and refueling pipeline space – STOP (Lack of Control)

1.1.1.1.3 (C) Battery spaces is not in good condition – STOP (Lack of Control)

1.1.1.1.4 (C) Wood boards and sponges as a prop for battery – STOP (Desired Condition)

[13] RealityCharting

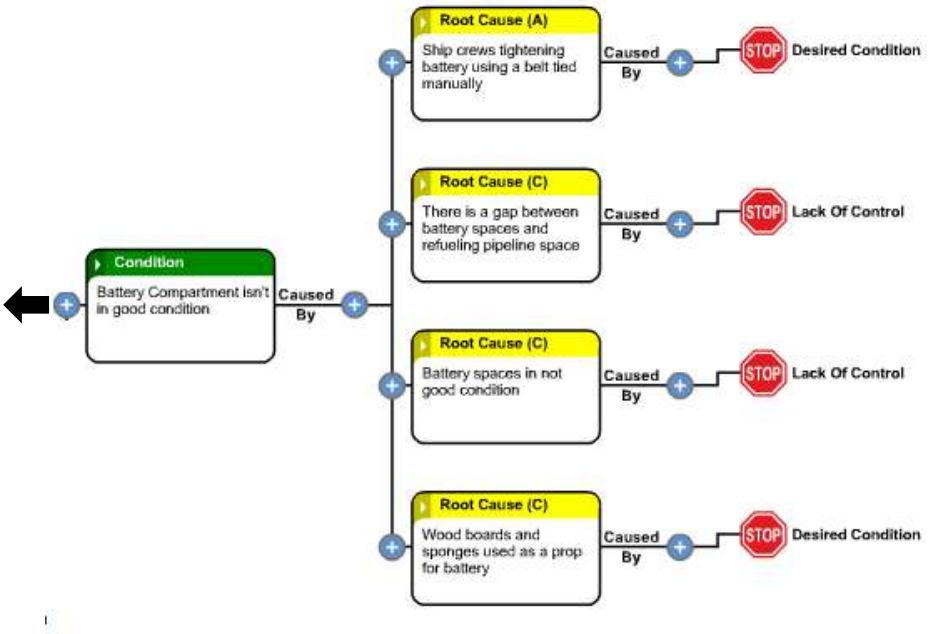



*Figure 4. 12 Chart (Explosion MV. Gili Cat) part 5* [14]

In the fifth stage is continued on Figure 4. 13 given the question why there are 1.2 (C) Flammable Material in the second stage. The answer of this question is as follows:

1.1 Why are there flammable materials?
- 1.1.1 (A) Ship crews were spilling fuel when refueling
- 1.1.2 (C) Gasoline on the LEL and UEL Range (1,4% - 7,6%)
- 1.1.3 (C) Refueling pipe is not in good condition

[14] RealityCharting

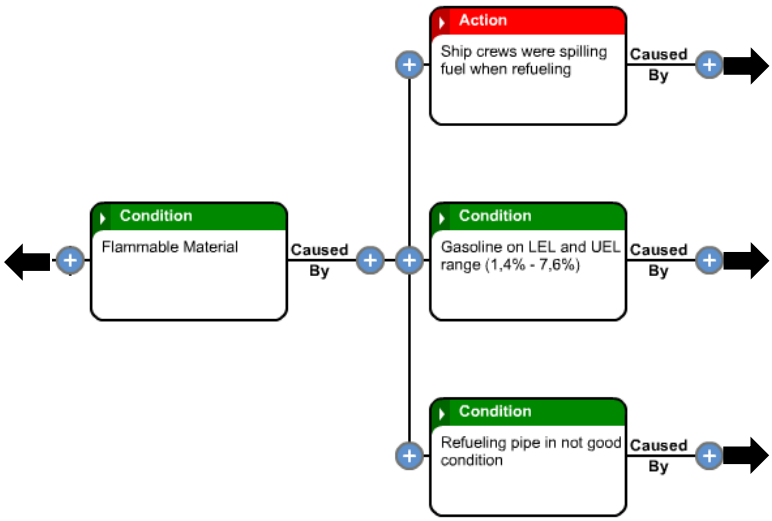



*Figure 4. 13 Chart (Explosion MV. Gili Cat) part 6* [15]

In the sixth stage is continued on Figure 4. 14 given the question Why 1.2.1 (A) Ship crews were spilling fuel when refueling and Figure 4. 15 Why there are 1.2.2 (C) Gasoline on the LEL and UEL Range (1,4% - 7,6%). Answers of this question are as follows:

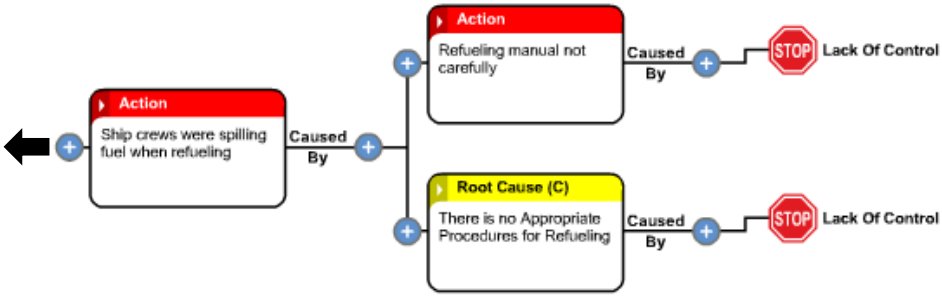



*Figure 4. 14 Chart (Explosion MV. Gili Cat) part 7* [16]

1.2.1 Why ship crews were spilling fuel when refueling?

1.2.1.1 (A) Refueling manual not carefully - STOP (Lack of Control)

[15] RealityCharting
[16] RealityCharting

1.2.1.2 (C) There is no appropriate procedures for refueling - STOP (Desired Condition)

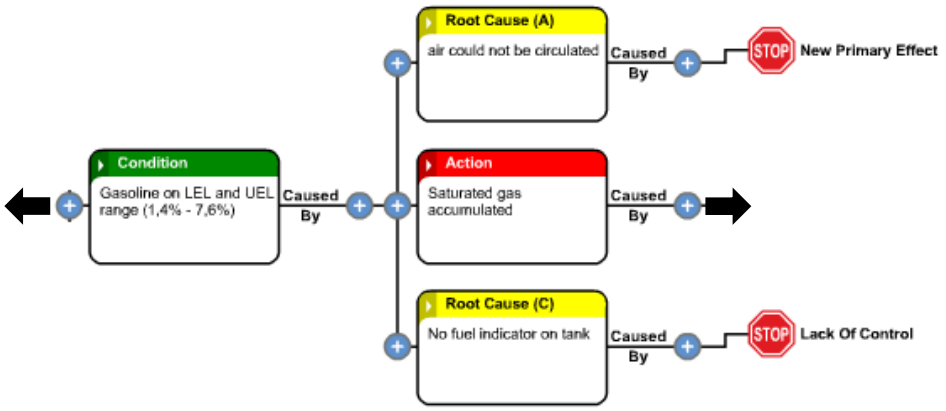



*Figure 4. 15 Chart (Explosion MV. Gili Cat) part 8* [17]

1.2.2 Why there are gasoline on the LEL and UEL range (1,4% - 7,6%)?

1.2.2.1 (A) Air could not be circulated - STOP (New Primary Effect)

1.2.2.2 (C) Saturated gas accumulated

1.2.2.3 (C) No fuel indicator on tank – STOP (Lack of Control)

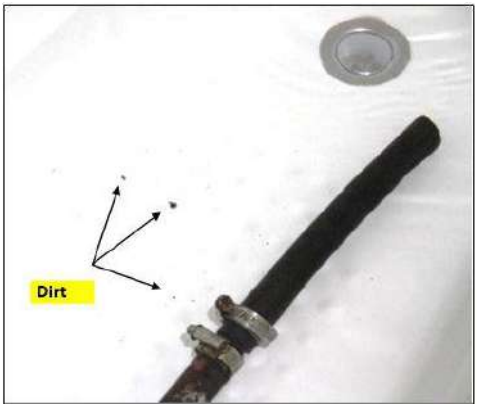



*Figure 4. 16 Evidence for Air could not be circulated* [18]

[17] RealityCharting
[18] NTSC Investigation

Evidence for Air could not be circulated is described in Figure 4. 16. Figure 4. 16 describe that the connector of venting pipe is corroded. Dirt inside pipe caused by corrosion in venting pipe connector made air circulation was not working well. Saturated gas accumulated and gas cannot release.

In the seventh stage is continued on Figure 4. 17 given the question why are there 1.2.2.2 (C) Saturated gas accumulated in the sixth stage. The answer of this question is as follows:

1.2.2.2 Why are there saturated gas accumulated?
1.2.2.2.1 (C) Venting pipe is not in good condition
1.2.2.2.2 (C) Venting pipe mounting moved position – STOP (Desired Condition)
1.2.2.2.3 (C) There is no venting pipe in compartment beside fuel tank – STOP (Desired Condition)

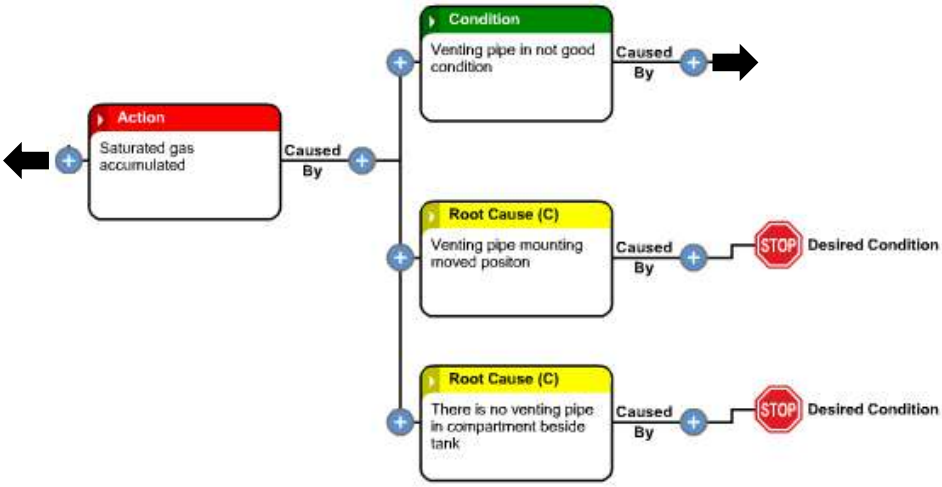



*Figure 4. 17 Chart (Explosion MV. Gili Cat) part 9* [19]

In the eight stage is continued on Figure 4. 18 given the question why on every answer in the seventh stage. The answer of each question is as follows:

[19] RealityCharting

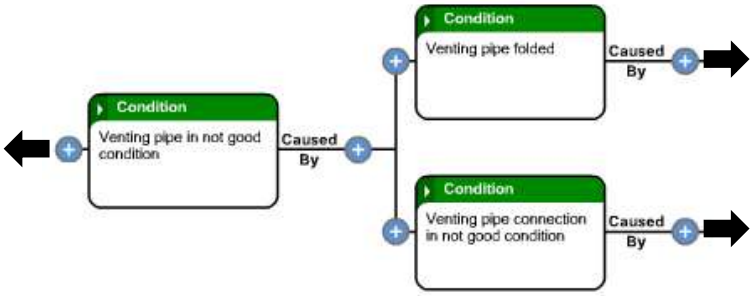



*Figure 4. 18 Chart (Explosion MV. Gili Cat) part 10* [20]

1.2.2.2.1 Why the venting pipe is not in good condition?
1.2.2.2.1.1 (C) Venting pipe folded
1.2.2.2.1.2 (C) Venting pipe connection is not in good condition

Evidence for venting pipe mounted moved position is described in Figure 4. 19. Figure 4. 19 describe that the previous venting pipe mounted was not used anymore and ship owner do the modification of venting pipe mounting. The modification made caused by MV. Gili Cat II operate always in trim by stern condition but a new modification venting pipe system is not work well, said NTSC Investigator. Present venting pipe design is not work well so saturated gas cannot release through the air. An unused venting pipe is closed by bolt.

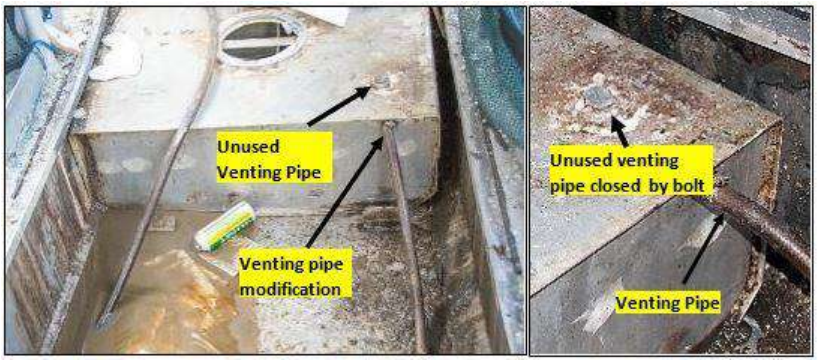



*Figure 4. 19 Evidence for venting pipe moved position*[21]

[20] RealityCharting
[21] NTSC Investigation

In the ninth stage is continued on Figure 4. 20 given the question why are there 1.2.2.2.1.1 (C) Venting pipe was folded in the eight stages. The answer of this question is as follows:

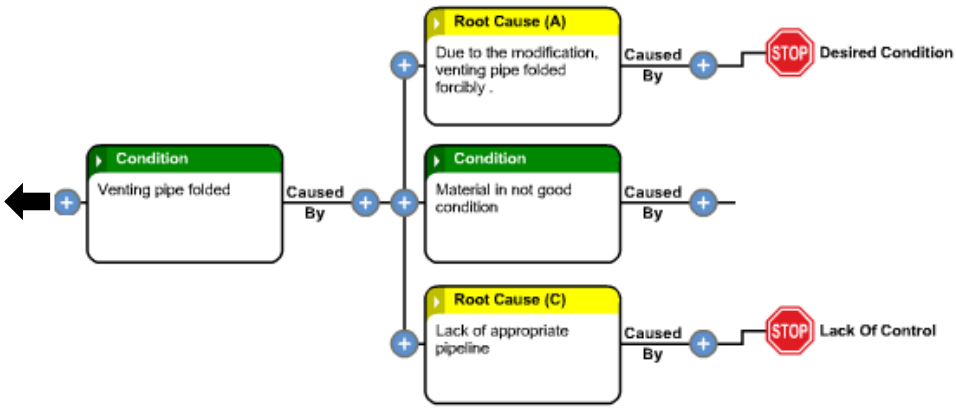



*Figure 4. 20 Chart (Explosion MV. Gili Cat) part 11* [22]

1.2.2.2.1.1 Why venting pipe was folded?

1.2.2.2.1.1.1 (A) Due to the modification, venting pipe folded forcibly – STOP (Desired Condition)

1.2.2.2.1.1.2 (C) Material is not in good condition

1.2.2.2.1.1.3 (C) Lack of an appropriate pipeline – STOP (Lack of Control)

There are evidences for each cause. Those evidences for venting pipe easily removable, plastic pipe inserted between two pipe connections, and there is an insulation tape blocking the hole in the pipe connection are described in Figure 4. 21, Figure 4. 22, and Figure 4. 23.

[22] RealityCharting

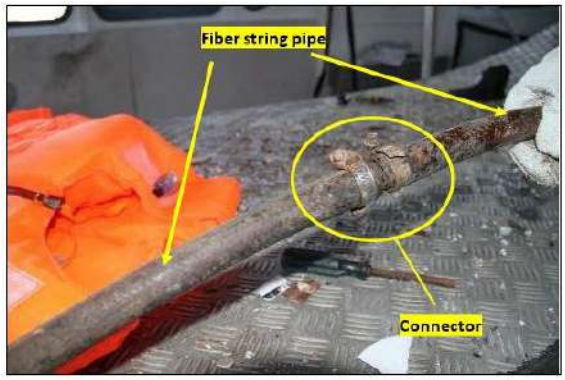



*Figure 4. 21 Evidence for Venting pipe connector bad condition*[23]

Bad condition of venting pipe connector cause saturated gas of fuel cannot release well. Corrosion of the connector made

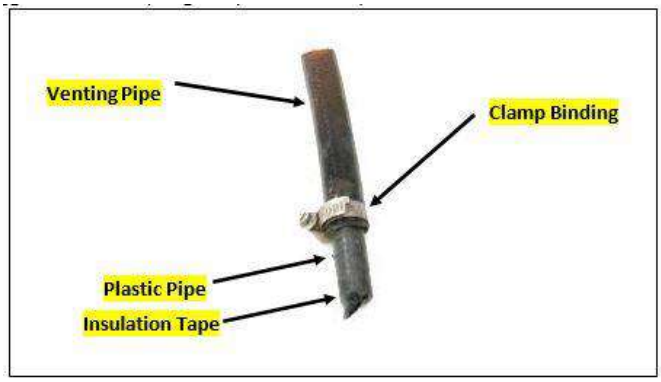



*Figure 4. 22 Evidence for plastic pipe inserted between two pipes*[24]

[23] NTSC Investigation
[24] NTSC Investigation

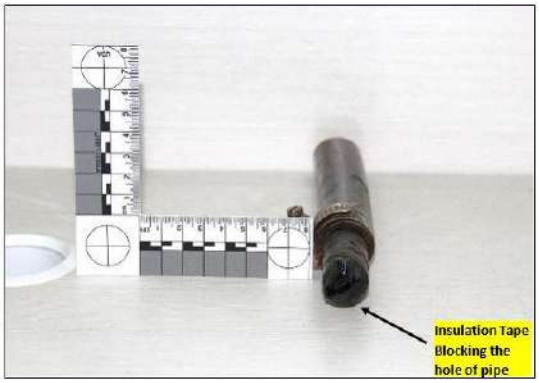



*Figure 4. 23 Evidence for insulation tape blocking venting pipe hole*[25]

In the tenth stage is continued on Figure 4. 24 given the question why are there 1.2.2.2.1.2 (C) Venting pipe connection is not in good condition in the eight stages. The answer of this question is as follows:

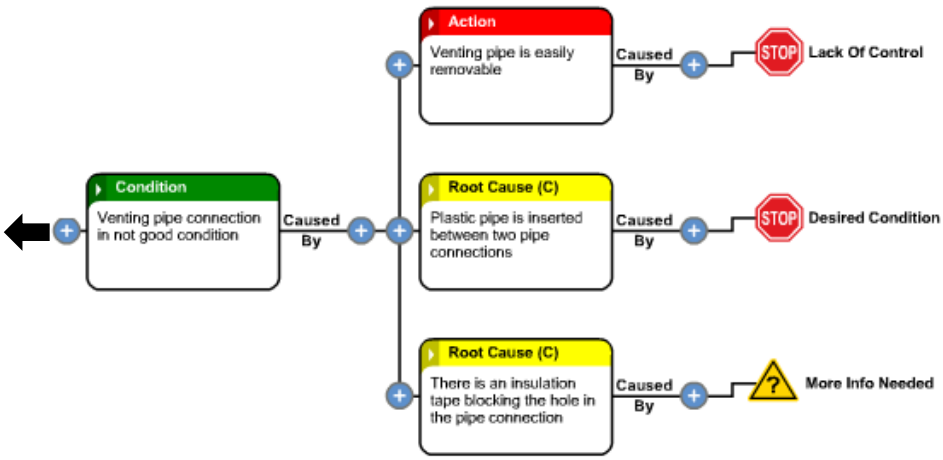



*Figure 4. 24 Chart (Explosion MV. Gili Cat) part 12* [26]

1.2.2.2.1.2 Why the pipe venting pipe connection is not in good condition?

1.2.2.2.1.2.1 (A) venting pipe is easily removable – STOP (Lack of Control)

1.2.2.2.1.2.1 (C) Plastic pipe is inserted between two pipe connection - STOP (Desired Condition)

[25] NTSC Investigation
[26] RealityCharting

1.2.2.2.1.2.2 (C) There is an insulation tape blocking the hole in the pipe connection - STOP (More Info Needed)

Evidence for venting pipe folded described in Figure 4. 25. Venting pipe folded are caused by design is not good. Bad design makes venting pipe folded forcibly so saturated gas cannot release. Venting pipe is using flexible hose. If the flexible hose is folded forcibly time by time the pipe condition is getting worse.

*Figure 4. 25 Evidence for venting pipe folded*[27]

In the eleventh stage is continued on Figure 4. 26 given the question why are there 1.2.2.2.1.1.2 (C) Material is not in good condition in the ninth stages. The answer of this question is as follows:

1.2.2.2.1.1.1 Why the material is not in good condition?
- 1.2.2.2.1.1.1.1 (A) Ship crews did not check well - STOP (Lack of Control)
- 1.2.2.2.1.1.1.2 (A) Ship crews did not check regularly - STOP (Lack of Control)
- 1.2.2.2.1.1.1.3 (C) Venting pipe location is difficult, to checked - STOP (Lack of Control)
- 1.2.2.2.1.1.1.4 (C) Not using material standards - STOP (More Info Needed)

[27] NTSC Investigation

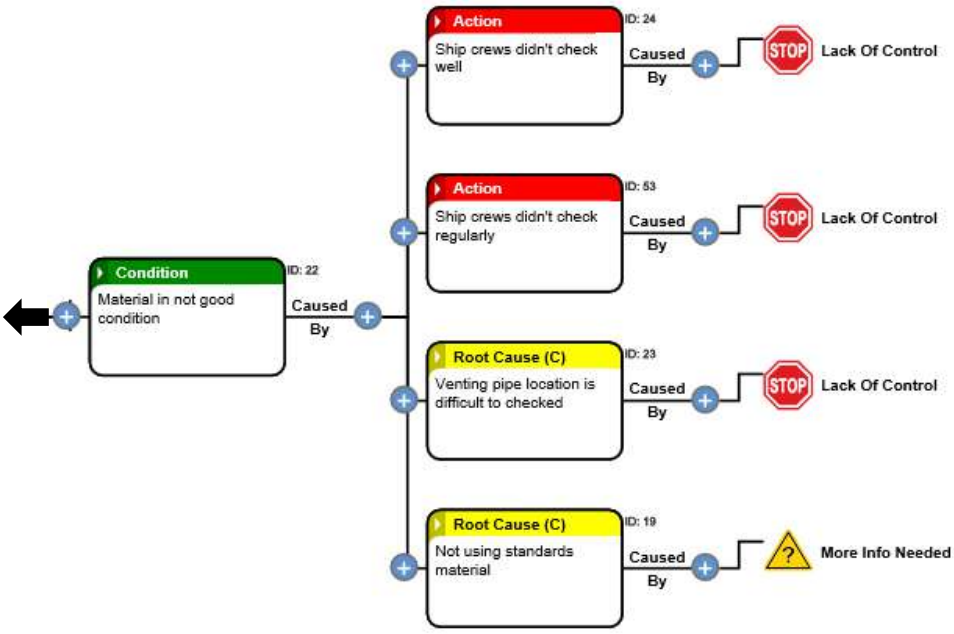



*Figure 4. 26 Chart (Explosion MV. Gili Cat) part 13* [28]

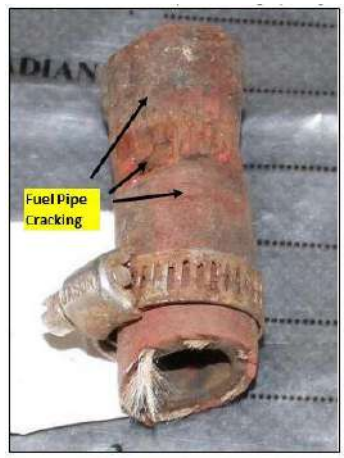



*Figure 4. 27 Evidence for Material is not in good condition (Cracking)*[29]

Evidence for material is not in good condition in Figure 4. 27. Figure 4. 27 describe that fuel pipe is cracking and brittle. Cause of this condition, fuel can get out from cavities of the cracking pipe. This condition is very dangerous and become fire/explosion possibility.

[28] RealityCharting
[29] NTSC Investigation

Fuel pipe cracking possible happen caused by less maintenance, location is difficult to checked, and not using standard material.

In the twelfth stage is continued on Figure 4. 28 given the question why on every answer in the fifth stage. The answer of that question is as follows:

2.2.3 Why the refueling pipe is not in good condition?

1.2.3.1 (A) Ship crews did not check well - STOP (Lack of Control)

1.2.3.2 (A) Ship crews did not check regularly - STOP (Lack of Control)

1.2.3.3 (C) Not using material standards - STOP (Desired Condition)

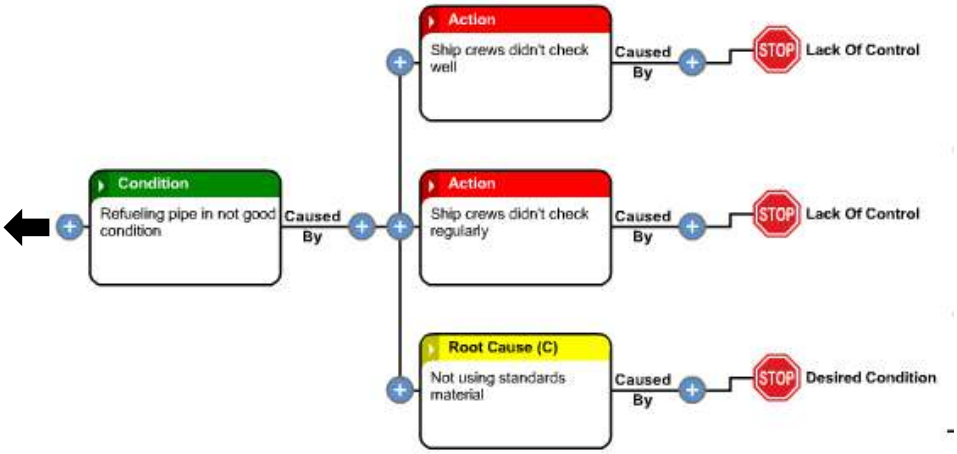



*Figure 4. 28 Chart (Explosion MV. Gili Cat) part 14* [30]

In the thirteenth stage is continued on Figure 4. 29 given the question why are there 1.3 (C) Oxygen in the second stage. The answer of this question is as follows:

[30] RealityCharting

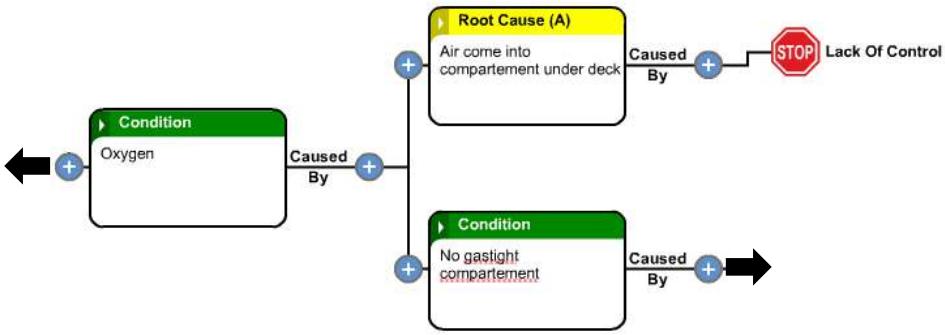



*Figure 4. 29 Chart (Explosion MV. Gili Cat) part 15* [31]

1.3 Why there is Oxygen?

1.3.1 (A) Air come into compartement under deck – (Lack of Control)

1.3.2 (C) No gastight compartment

In the fourteenth stage is continued on given the question why there is 1.3.2 (C) no gastight compartment in the thirteenth stage. The answer of that question is as follows:

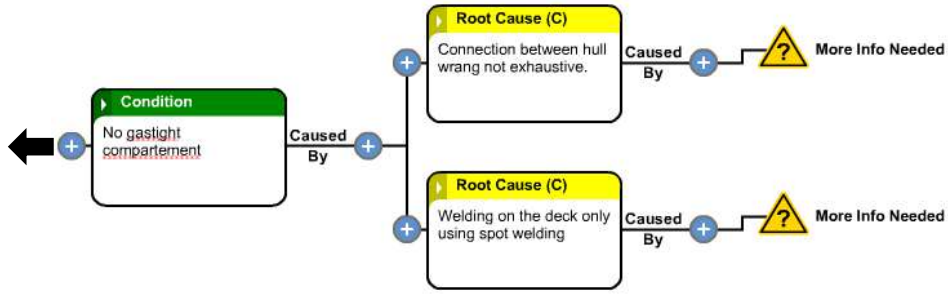



*Figure 4. 30 Chart (Explosion MV. Gili Cat) part 16* [32]

1.3.2 Why the compartement is not watertight?

1.3.2.1 (C) Connection between hull wrang not exhausted - STOP (More Info Needed)

1.3.2.2 (C) Welding on the deck only using spot welding - STOP (More Info Needed)

[31] RealityCharting
[32] RealityCharting

There is an evidence for each cause. Evidence for air come into compartement under deck, connection between hull wrang is not exhausted, and welding no the deck only using spot welding are described in Figure 4. 31.

*Figure 4. 31 Evidence for welding only using spot welding*[33]

### 4.3.3 Identify Possible Effective Solution

Identify Possible Effective Solution is a phase that we must follow to continue after creating chart. At this stage, team members will identify any effective solution that can be recommended. The solution provided by the team members. Possible solution will be selected that can be implemented in accordance with the judgment by expertise. In recommending solutions in Apollo root cause analysis methods, there are several criteria check. The criteria check and possible solution of MV. Gili Cat II explosion of RealityCharting application are described in Appendix 1.

There are some rules or criteria that should be followed before identifying any possible solution. Those criteria are as follows:

- Does this solution prevent recurrence?
- Is this solution within your control?
- Does this solution meet your goals and objectives?
- Does this solution cause other unacceptable problems that you are aware of?

[33] NTSC Investigation

In this thesis, there are some possible solution that could be implemented regarding to MV. Gili Cat II explosion. Those possible solutions are:

- Recommendation about electrical system design
- Using standard material
- Recommendation about piping system design
- Crews was given special training
- Ship owner should be recruiting the crew that has been certified
- Work procedures based on ISM Code
- Welding according to standards

### 4.3.4 Implement best solution

Implement best solution is the stage where members choose the best solutions that have been recommended. There are some assessments that need to be considered for choosing a solution that will be implemented. Solution assessment that has been recommended is intended that consider which solution is best. The best solution would be implemented on the case under evaluation. In the solution assessment, there are several criteria. These criteria include total cost, ease of implementation, the probability of recurrence, and etc. As in each of these criteria have rank and weight. Ranking is the value of each of these criteria that contain limitation on any number on any criteria. In conducting this assessment, there are several examples of criteria, but not all of the criteria I use in this solution assessment. Solution assessment example that I have done in this method is described in appendix 1.

There are some criteria that used in this thesis. Those criteria are probability of recurrence, ease of implementation, effectiveness, and total cost. Each criterion has score. Criteria and score that used in this thesis are selected by discussing with NTSC investigator. Detail of criteria and score of RealityChrating solution assessment described in Table 4. 3. Detail Solution Assessment questionnaire will be attach in Appendix 3.

*Table 4. 3 Solution Assessment Criteria and Score Detail*[34]

[34] RealityCharting

| No. | Criteria | Score |
|---|---|---|
| 1 | Probability of Recurrence | 1 (>75%) to 4 (<10%) |
| 2 | Ease of Implementation | 1 (Difficult) to 4 (Easy) |
| 3 | Effectiveness | 1 (Not Eff.) to 4 (Very Eff.) |
| 4 | Total Cost | 1 (Expensive) to 4 (Low-Cost) |

The description of each criterion is:

- Probability of Recurrence: The probability of same cases or similar cases recurred. The point is, if a solution is implemented then how is the probability or how likely the occurrence of the case can happen again.
- Ease of implementation: Ease of implementation is how difficult the solution can be implemented (Technical Difficulties).
- Effectiveness: Effectiveness is how effective is the solution when implemented.
- Total cost: Total cost is how much the cost needed if the solution is implemented.

In conducting this assessment, the process will be done by expertise in the field. The assessment will be done by spreading questionnaires to some respondents. NTSC is selected to be respondents. Results of solution assessment will be described as Table 4. 4 following:

*Table 4. 4 Solution Assessment* [35]

| Solution | Criteria (1) | Criteria (2) | Criteria (3) | Criteria (4) | Total |
|---|---|---|---|---|---|
| Recommendation about electrical system design | 2,67 | 3,33 | 3,67 | 2,33 | 12,00 |
| Using standard material | 3,33 | 3,67 | 4,00 | 3,00 | 14,00 |
| Recommendation about piping system design | 3,33 | 3,33 | 4,00 | 2,67 | 13,33 |
| Crews was given special training | 2,67 | 3,67 | 3,33 | 2,67 | 12,33 |
| Ship owner should recruiting the crew that has been certified | 2,67 | 3,67 | 3,67 | 2,67 | 12,67 |

[35] RealityCharting

| Solution | Criteria (1) | Criteria (2) | Criteria (3) | Criteria (4) | Total |
|---|---|---|---|---|---|
| Work procedures based on ISM Code | 3,33 | 3,33 | 3,33 | 2,33 | 12,33 |
| Welding according to standards | 3,33 | 3,00 | 4,00 | 2,33 | 12,67 |

### 4.3.5 Finalizing the report

Finalize report is the last stage in the completion of Apollo Root Cause Analysis method. In the RealityCharting software, report creation process will be completed automatically. Creating report automatically process is one of the advantages of this method, for the manufacture report will be much easier than using other methods. Creating report process may complete if every component in the first stage to the fourth stage have been completed. Here is the result of any incident report on the application RealityCharting. Finalize report described in Appendix 2.

## 4.4 Electrical System Recommendation

Conditions that are not in accordance with the standards on the MV. Gili Cat II electrical system became the main cause of the explosion. These main caused are igniter (Igniter, Flammable Material, and Oxygen). The conditions that are not in accordance with the electrical system in the vessel are:

- Bad Electrical wiring system
  1) Tightening battery using a belt tied manually
  2) Wood boards and sponges used as a prop for battery
  3) Switch and contacts pole are not protected with isolator
  4) Battery Spaces is not in good condition
  5) There is a gap between battery spaces and refueling pipeline space
  6) Brocken Socket
- Static electricity around the tank and hull
- There is no earthing system

The electrical equipment that will be evaluated and given recommendations in this thesis is only related to the general electrical requirements, the extra low voltage electrical system and the battery, as well as recommendations that support the electrical system.

Recommendations on this system refer to NCVS Chapter V (Machinery & Electrical) standard. Here is an explanation of the recommendation regarding electrical system in this thesis.

### 4.4.1 General Electrical Requirements

1. Design
   Electrical installations should be such that:
   - All electrical auxiliary services necessary for maintaining the ship in normal operational and habitable conditions will be ensured without recourse to the emergency source of electrical power;
   - Electrical services essential for safety will be ensured under various emergency conditions; and
   - The safety of passengers, crew and ship from electrical hazards will be ensured

2. Safety Protection
   Protection must be provided to prevent inadvertent contact by personnel and passengers with parts of the electrical installation. Minimization of risk of fire, damage, and physicals injury must include overcurrent protection, appropriate insulation, appropriate construction, fault indication, safety trips, and effective operational and maintenance procedures.

3. Isolation
   Electrical installations, and parts of installations, must be provided with isolation devices to prevent or remove hazards associated with abnormal operation (e.g. faults such as short circuits) and to allow maintenance of electrical equipment.

4. Battery
   Battery installations must be designed and installed to eliminate or minimize risks associated with the emission of gases, corrosive fluids, electro-chemical corrosion, movement, mechanical damage, and exposed terminals.

5. Earthing and Bonding
   - Earthing

1) Earthing systems
   a. Method of earthing
      The method of earthing for a.c. systems at voltages greater than 50 V Shall be:
      i. A multiple earthed neutral (MEN) system; or
      ii. An isolated earth system.
   b. The method of earthing for d.c. systems shall be:
      i. A negative earth; or
      ii. An isolated earth.

   Notes: An installation may include mixed methods of earthing. Earthing systems should be mixed only after consideration of the possible fault currents in each system.

2) Main earth connection
   In a vessel with a hull constructed wholly of metal, the main earth conductor shall be taken from the earth terminal, bar, or link at the main switchboard to an earth electrode solidly connected to the hull. In a vessel with a hull not constructed wholly of metal, the main earth conductor shall be taken from the earth terminal, bar, or link at the main switchboard to an earth electrode solidly connected to an earth plate the main earth conductor shall run in as direct a manner as practicable and shall not be connected to any other appliance.

3) Multiple Earth Neutral (MEN) earth system
   In an MEN earthing system, the neutral to earth bond should be made at each generator. Note: The MEN bond is switched out of the system because the shore power/vessel supply changer over switch operates in all live conductors.

4) Isolated earthing system
   An electrical system isolated from earth shall employ an earth fault monitor or insulation resistance monitor.

Where earth lamps are used for this function, the lamps shall:

a. Be of a filament type;
   i. not exceed 30 W;
   ii. be of the same color;
b. Be placed not more than 125mm apart; and
c. Have a lamp test capability. Each generator in an isolated earth system shall have an earth fault monitor or insulation resistance monitor.

5) Earthing and bonding electrodes

All connections to the vessel's hull or earth plate shall:

a. Be accessible for inspection;
b. Be secured by means of a screw or stud used for this purpose only with a diameter suited to the size of the earth conductor but not less than 6 mm;
c. Be protected against corrosion; and
d. Remain unpainted.

Note: Care should be taken to ensure bright metallic surfaces at the contact areas immediately before the nut or screw is tightened. The use of washers of a type that bite into the metal is recommended. To protect against electrolytic corrosion, care must be taken in the choice of metals and methods used to make the connection. Where necessary the joint should be protected with anti-oxidation grease. Earth electrodes used for the connection of lightning protection to a vessel's hull or earth plate shall not be used for connection of protective earthing, equipotential bonding or communication equipment earthing.

6) Earth plates

All electrical installations on vessels of non-metal hull construction shall incorporate an earth plate that complies with the following:

a. The earth plate shall be:

i. Manufactured from copper or other material of equivalent mechanical and electrical properties; and
ii. Securely attached with non-corrodible fastenings to the hull of the vessel.

b. The earth plate shall be positioned so that it is immersed always during operation of the vessel.
c. The earth plate shall have an area of at least 0.25 m2, and shall be at least 3.2 mm thick.
d. Connections to the earth plate shall comply with clause.

If more than one earth plate is used, all earth plates shall be equipotential bonded. The same earth plate may be used for protective earthing, functional earthing of communications equipment, and lightning protection. Main earth (protective earth), functional earthing and lightning down conductors shall be run separately to the earth plate(s) and connected by separate electrodes to the earth plate(s).

- Bonding
  Equipotential bonding shall:
  1) have a resistance to earth of less than 0.5 ohm; and in nonmetallic vessels, be provided between all engine bedplates, generator frames, metallic elements of the fuel system, fixed metal objects with a surface area more than $0.4m^2$, and the earth plate.
  2) To help dissipate possible static build up and to minimize the effects of electrolytic corrosion it is recommended that metallic fittings, particularly those in con-tact with the sea, are bonded to the main earth system.

6. Cables and wiring systems
   - Wiring systems
     Cable and wiring systems shall meet the requirements of IEC 60092-352 and IEC 60092-401.
   - Duplicate supply

Where a duplicate or alternative supply is required (e.g. alternative supplies for the navigation light panel), the two cables shall be routed separately to avoid the risk of concurrent damage to both cables.

7. Unacceptable components materials and methods
   The following components, materials and methods are not suited to the marine environment and shall not be used:
   - Re-wire able fuses.
   - Hull return, except for cathodic protection systems.
   - Aluminum conductors.

8. Equipment and accessories in hazardous area
   Where practicable, electric equipment shall not be installed in a space where petroleum vapor or another hydrocarbon gas maybe accumulate. When equipment is installed in such a space it shall comply with a recognized standard for prevention of ignition of flammable atmosphere.

9. Commissioning-inspection and testing
   - Tests
     At the conclusion of construction, modification, or repairs the electrical system, equipment or part shall be inspected and tested in accordance with IEC 92-401 before being put into service.

     Commissioning tests shall include, as a minimum, the correct operation (i.e. in accordance with manufacturers specifications and the objectives and requirements of this clause) of the following equipment where fitted :
     1) generator operation including:
        a. engine governors;
        b. parallel operation;
        c. load sharing;
        d. voltage regulator operation by instantaneous loading and unloading of generator; and

e. safety devices, such as overspeed trips, reverse power trips, over current trips, load shedding, together with the associated controls and alarms.

2) load testing of motors;
3) overload alarm circuits of essential service motors;
4) main engine safety alarms and trips;
5) machinery and equipment that incorporates remote controls, remote stops and limit switches;
6) emergency stop circuits;
7) vessel's alarm systems; and
8) other systems and equipment installed in the vessel.

- Test results
  All test results shall be recorded and the test results shall remain with the vessel's documentation. Test results should be dated, accurate, legible and retained for the life of the vessel.

10. Designs parameters
    Unless otherwise specified, electrical equipment shall be designed for an ambient temperature of at least 45° C.

### 4.4.2 Extra-Low Voltage System and Batteries

1. Scope
   These rules are about the requirements for electrical equipment and electrical installations for extra-low voltage systems. (voltages up to 50 V a.c and 120 V d.c)

2. Engine Starting Cables
   Engine starting cables shall:
   - Protected from mechanical damages;
   - Terminals protected from mechanical damages and from contacts with conductive materials;
   - Be as short in length as with the starter motor batteries;
   - Be routed to avoid the possibility of coming into contacts with flammable materials or sheathed with some material resistant to the effect of it;
   - Be of adequate size for the expected cranking current and to minimize voltage drop;

- Be connected directly to the starter via the starting relay contacts; and
- Be suitably sealed at terminals in such a manner as to reduce corrosion.

Notes: Cables size of starter motor should be based on manufacturers specification. The starting motor relay shall be mounted directly on the starter or adjacent to it.

3. Switches and Circuit Protection
   In isolated systems, switches and circuit protection shall interrupt all active conductors i.e. double pole switches are to be used.

4. Batteries and Battery Installation
   - Battery Isolation
     All batteries shall be controlled by an isolation switch operating in all active conductors. Isolation switches shall be located as close as practicable to the battery, and cables between the battery and isolating switch shall be double insulated or installed in a wiring enclosure throughout their entire length
   - Battery location and mounting
     a. Battery location
        To limit voltage-drop in cables, starting batteries should be located as close as practicable to the engines they serve while minimizing the risk of hydrogen released by the battery being ignited by a spark from the starter motor.
     b. Mechanical protection
   - Battery boxes
     Battery boxes shall be:
     a. Capable of containing the whole volume of electrolyte and using chemically resistant materials; and
     b. Mounted and arranged to prevent movement of the battery cause the motion of the vessel.
   - Battery compartments
     Batteries shall be mounted in drip trays or containers of a chemically resistant material that can contain the total volume of electrolyte. Mounting arrangements for the

containers and the batteries shall prevent movement of the battery cause the motion of the vessel.

- Battery Housing
  Batteries, or sets of batteries, charged by chargers where the sum of all chargers is greater than 2 kW in total shall be housed in a compartment dedicated to batteries only. Battery compartments shall be well ventilated to the open deck. Cable entries to battery compartments shall be gas tight.
- Switches in battery compartments
  Switches and other circuit interrupting devices shall not be housed in battery boxes, battery compartments or dedicated battery rooms. These devices shall be mounted as close as practicable, but external to, these housings.
- Battery protection
  Batteries supplying essential services, excluding engine starting batteries, shall have short circuit protection as a minimum protection for overcurrent. Engine starting batteries shall have either:
  a. Short circuit protection; or
  b. Mechanical protection of the starting cables.
  c. For all other battery circuits, short circuit and overload protection shall be provided.

5. Ventilation of Batteries and Battery Compartments
   - General
     Ventilation is needed to avoid the accumulation of hazardous gases. The accumulation of hazardous gases can cause a risk of fire or explosion, so battery compartments, rooms, and boxes shall be ventilated.
   - Minimal exhaust rate
     The concentration of hazardous gases should be below 2 percent. The minimum exhaust ventilation rate is needed by following formula (4.1):

     $$q_v = 0{,}006 \times n \times l \qquad (4.1)$$

     Where:

$q_v$ = the minimum exhaust ventilation rate, in liters per second
n = the number of battery cells
I = the charging currents, in amperes

- Natural ventilation
  For natural ventilation, the minimum size of inlet and outlet vents is given by following formula (4.2):

$$A = 100 \times q_v \quad (4.2)$$

  Where:
  A = the minimum area of vent, in square centimeters
  $q_v$ = the minimum exhaust ventilation rate, in liters per second
- Mechanical ventilation
  Mechanical ventilation is needed to meet the minimum exhaust rate (qv) the following shall apply:
  a. exhaust air shall be discharged outside the ship's structure;
  b. fans shall not be located within a duct (i.e. best mounted at discharge end of duct);
  c. exhaust ducting shall have a positive gradient over the full length of the duct and shall not connect to another ductwork;
  d. non-sparking material shall be used for fan blade and fan housing;
  e. controls for the fan shall be external to the compartment being ventilated; and
  f. air flow shall be monitored and an audio/visual flow alarm fitted.

## 4.5 Fuel Oil System Recommendation

Conditions that are not in accordance with the standards on the MV. Gili Cat II fuel oil system became the main cause of the explosion. These main caused are flammable material (Igniter, Flammable Material, and Oxygen). The conditions that are not in accordance with the fuel oil system in the vessel are:

- There is a fuel spill when refueling

- Refueling procedures
- Venting pipe system (design, condition, etc.)
- Material used in the existing condition

The fuel oil system equipment that will be evaluated and given recommendations in this thesis is only related to the fuel tanks, safety arrangements for power-operated fuel pumps and motors, additional requirements for fuel system, and Refueling safety tips based on NFPA. Recommendations on this system refer to NCVS Chapter V (Machinery & Electrical) standard and NFPA. Here is an explanation of the recommendation regarding electrical system in this thesis.

### 4.5.1 Fuel Tanks

1. Fuel tank types
   - Non-potable fuel tanks built-in
     Fuel tanks that are integral to the vessel's hull structure
   - Non-potable fuel tanks freestanding.
     Fuel tanks that are not integral to the vessel's hull structure, but fitted to or permanently located on the vessel
   - Portable fuel tanks.
     Fuel tanks of 25 liters capacity or less, and which are intended to be re-moved from the vessel for filling.
2. Common requirements for non-portable fuel tanks of both free-standing and built-in types
   - Location
     Location for non-portable fuel tanks shall not be fitted in the following locations:
     1) Over stairways and ladders.
     2) Over hot surfaces.
     3) Over electrical equipment.
     4) In any location near a source of ignition.
   - Pressure testing
     Non-portable fuel tank shall be pressure tested to 2.5 meters of fresh water above the top of the tank, or to the maximum head to which the tank may be subject to in service, whichever is the greater. Tank shall be tested before installation into the vessels.
   - Venting

Tank shall be vented into the open air. Area of the venting pipe shall not to be less than 1.25 times the area of the filling pipe if the tank is filling affected by pump. The pipe shall terminate in a gooseneck on the open deck. Where the diameter of the pipe outlet exceeds 18 mm, a corrosion-resistant wire gauze screen shall be fitted. A short flexible section of hose of length no more than 760 mm may be incorporated into the vent pipe for vibration damping or to facilitate installation. Pipe shall be made of reinforced synthetic rubber of a type resistant to fuel, salt water and vibration. The flexible section of hose shall be fastened to the rigid section of the vent with two corrosion-resistant clips at each end.

- Inspection opening
  The freestanding type and less than 800 liters capacity, shall be fitted with an inspection opening to facilitate cleaning and inspection.
- Fuel shut-off
  A fuel shut-off valve shall be fitted in each tank outlet line. Nonmetallic piping and fittings shall not be fitted in the line between the tank and this shut-off valve. It located outside a machinery space in a position not likely to be isolated by a fire in the machinery space. They shall be capable of operating when exposed to flame and heat from a fire.
- Filling pipes for non-portable fuel tanks
  Non-portable fuel tanks shall incorporate a permanent filling pipe. It should extend from the open deck to the tank. A short flexible section of hose of length no more than 760 mm may be incorporated into the filling pipe for vibration damping or to facilitate installation. The flexible section of hose shall be fastened to the rigid section of the vent with two corrosion-resistant clips at each end.

3. Specific requirements for built-in fuel tanks which are integral to the vessels hull structure
   - Arrangements
     Fuel tanks shall not be located forward of the collision bulkhead.
   - Fuels having a flashpoint below 60° C

Built-in fuel tanks shall not be used to contain fuels having a flash-point below 60°C.

- Baffles
  Baffle plates shall be fitted in built-in fuel tanks to reduce the surging of the tank contents.

### 4.5.2 Safety arrangements for power-operated fuel pumps

1. Relief Valving
   Relief valve discharging back to the suction side of the pump shall be fitted, if the closed discharge pressure exceeds the maximum design working pressure of the discharge system.
2. Stop valves
   Stop valves shall be fitted on the suction and discharge lines of cargo oil, fuel transfer and fuel pressure pumps.
3. Means of stopping
   A fuel transfer pump or cargo oil pump shall be fitted with means to stop the pump from both inside and outside the space in which it is located. The remote fuel transfer pump or cargo oil pump shut-down arrangements shall be capable of operating when exposed to flame and heat from a fire within the space containing the pump.
4. Fuel filters
   Transparent filter casings of plastic or glass shall be resistant to both mechanical impact and thermal shock, and shall either be fitted with guards or located in protected positions.

### 4.5.3 Additional requirements for fuel system

1. Gravity feed fuel systems
   Gravity feed fuel systems shall not be used for the non-portable tanks of capacity more than 10 liters.
2. Fuel tank capacity
   Non-portable fuel tanks should be no larger than that necessary for the intended service of the vessel, but should be of sufficient capacity to prevent them having to be filled while in service.
3. Fuel tank contents measurements
   It used for determining the amount of fuel contained in the tank. The cap provided on the sounding pipe for the insertion of the sounding rod shall have a maximum clear opening of 15 mm diameter.

4. Fuel tank location
   Tank shall be securely installed in a location remote from the engine, exhaust pipes and other potential sources of ignite.
5. Fuel filler pipe
   The fuel filler pipe for non-portable fuel tanks shall extend to a point close to the bottom of the tank. It used to reduce the backflow of inflammable vapors through the filling pipe.
6. Inspection
   Tanks should be able to be inspected externally.
7. Ventilation
   Each fuel tank shall also be fitted with a vent pipe, remote from the tank space vent, leading to a similar open space. They shall be separate and non-communicating, and shall be fitted with spark arresters (e.g. wire gauze diaphragms).
   NOTE: Additional ventilation of the fuel tank space may be provided by a flameproof fan. Alternatively, a gas detector may be fitted, having an audible or visual alarm located at the control position.
8. Electrical connections
   Electrical connections or wiring shall not be fitted anywhere within the tank space.
9. Electrical bonding
   Electrical bonding shall be provided to protect against the possibility of a spark arising from static charge causing an explosion. Tanks shall be earthed so that resistance to earth is less than 10 ohms.
10. Flexible piping
    Flexible pipe is used in the section of line between the engine bed and the fuel lift pump. It shall be resistant to heat, salt water, petroleum products and vibration and shall comply with a relevant national or international standard (SAE J 30 or equivalent).

### 4.5.4 Refueling Safety tips based on NFPA

1. Turn off vehicle's engine when refueling.
2. Keep gasoline and other fuels out of children's sight and reach.
3. Do not smoke, light matches or use lighters while refueling.
4. Pay attention when refueling.

5. If you must use any electronic devices, follow manufacturer's instruction.
6. Use only the refueling latch on the gasoline dispenser nozzle, if there is one.
7. Use only the refueling latch on the gasoline dispenser nozzle, if there is one.
8. After pumping gasoline, leave the nozzle for a few second to avoid drips.
9. If a fire starts while you're refueling, do not remove the nozzle from the vehicle or try to stop the flow of gasoline. Leave the area immediately and call for help.
10. Do not get in and out of your vehicle while refueling. It can cause electrostatic charge.
11. If you must get into the vehicle during refueling, discharge any static electricity by touching metal on the outside of the vehicle, away from the filling point, before removing the nozzle from your vehicle.
12. Use only approved portable containers for transporting or storing gasoline.
13. Never fill a portable container when it is in or on the vehicle.
14. When filling a portable container, keep the nozzle in direct contact with the container. Fill it only about 95 percent full to leave room for expansion.

### 4.5.5 Tank Design Recommendation

Tank design recommendation for MV. Gili Cat II is regarding to the NCVS Ch. V. In this recommendation, refueling for the tank is using appropriate pump. Pump that used in this recommendation is:

- Brand : HAINA PUMP
- Type : CYB-S-25-27
- Capacity : 3 $m^3$/h
- Head : 27 m
- RPM : 2900 rpm
- Shaft Power : 0,6 kW
- Motor : 3 phases
- Frequency : 50 Hz
- Model : YB801-2
- Power : 0,75 kW

Appendix 4 is described about detail calculation of pump and pipe selection, existing fuel tank design, and fuel tank design recommendation.

# CHAPTER 5
# CONCLUSION AND RECOMMENDATION

Based on the evaluation conducted through the evidence obtained from the investigation of the NTSC, General Arrangements, Daily report of MV. Gili Cat II, incident reports, etc., then continued with the analysis using Apollo Root Cause Analysis method. From this analysis then obtained the root cause result of MV. Gili Cat II explosion. Then followed by recommending suggestions related to electrical systems and fuel oil systems. Here are result that can be produced:

1. There are some conditions on the ship that became the main cause of the explosion. Conditions which cause an explosion as Igniter factors are:
    - Bad Electrical wiring system
        1. Tightening battery using a belt tied manually
        2. Wood boards and sponges used as a prop for battery
        3. Switch and contacts pole are not protected with isolator
        4. Battery Spaces is not in good condition
        5. There is a gap between battery spaces and refueling pipeline space
        6. Brocken Socket
    - Static electricity around the tank and hull
    - There is no earthing system on tank
2. Conditions which cause an explosion as flammable material factors are:
    - There is a fuel spill when refueling
    - Refueling procedures
    - Venting pipe system (design, condition, etc.) is not following the standard (NVSC Ch. V)
    - Material used in the existing condition
3. Conditions which cause an explosion as oxygen factors are:
    - Compartment below deck is not watertight
    - Only using a spot welding
4. The following recommendations related to Electrical system are:
    - Cable and wiring systems shall meet the requirements of IEC 60092-352 and IEC 60092-401.
    - Engine starting cables shall:
        - Protected from mechanical damages

    - Terminals protected from mechanical damages and from contacts with conductive materials
    - Be as short in length as with the starter motor batteries
    - Be routed to avoid the possibility of coming into contacts with flammable materials
    - Be connected directly to the starter via the starting relay contacts
    - Be suitably sealed at terminals in such a manner as to reduce corrosion.
- Earthing:
    - For a.c system (above 50 V) shall be using a multiple earthed neutral (MEN) system or isolated earth system
    - For d.c system shall be using a negative earth or an isolated earth system
- Batteries and Battery Installation:
    - All batteries shall be controlled by an isolation switch operating in all active conductors.
    - Starting batteries should be located as near as with the engine
    - Battery boxes shall use chemical resistant material and mounted or arranged to prevent movement of the battery cause the motion of the vessel.
    - Starting battery protection is needed. (Short circuit, Mechanical protection of starting cables, and overload protection)

5. The following recommendations related to Fuel Oil system are:
    - Non-portable fuel tank shall be pressure tested to 2.5 meters of fresh water above the top of the tank.
    - Tank shall be vented into the open air. The pipe shall terminate in a gooseneck on the open deck.
    - Area of the venting pipe shall not to be less than 1.25 times the area of the filling pipe if the tank is filling affected by pump.
    - Where the diameter of the pipe outlet exceeds 18 mm, a corrosion-resistant wire gauze screen shall be fitted.
    - A short flexible section of hose of length no more than 760 mm can be used for venting pipe and filling pipe.
    - Material of flexible pipe is using SAE J 30 or equivalent.
    - Using appropriate pump for filling tank cause tank capacity is more than 10 liters
    - Tanks should be able to be inspected externally.

- Tanks shall be earthed so that resistance to earth is less than 10 ohms.
- Safety arrangements for fuel pump and motors
    - Relief Valve
    - Stop Valve
    - Means of stopping
    - Fuel filters
- Refueling procedures is following “Refueling safety tips based on NFPA”

*"This page intentionally blank"*

# REFERENCES


Code, F., n.d. Chapter IV Fire Extinguisher. In: s.l.:s.n.

Code, F., n.d. Chapter VIII. In: s.l.:s.n., p. Regulation 2.5.

DKI, P., 2008. *Peraturan Daerah DKI Jakarta.* Jakarta, Patent No. 08.

Gano, D. L., 2011. *RealityCharting - Seven Steps to Effective Problem Solving and Strategies for Personal Success.* 1st ed. Richland: Apollonian Publications, LLC.

Grattan, R. M. K. M., 2010. *Fire Dynamics Simulator (Version 5) User's Guide.* Maryland, USA: s.n.

Hartin, E., 2007. Fire Development and Fire Behavior Indicators.

ILO, I. L. O., 1996. Accident prevention on board ship at sea and in port. In: *General shipboard safety and health considerations. Fire Prevention.* 2nd ed. Geneva: ILO.

IMO, I. M. O., 2004. *Fire Control Symbols.* s.l. Patent No. Res A. 952 (23).

IMO, I. M. O., 2004. *Fire Control Symbols.* s.l. Patent No. Res A. 654 (16).

KNKT, K. N. K. T., 2011. *Analisa Data Kecelakaan dan Investigasi Transportasi laut 2007-2011,* Jakarta: Kementrian Perhubungan.

Kundu, S. C., Divya, M. & Pradeep, K., 2007. *Delhi Business Review Vol.8, No.1.* Delhi: s.n.

NFPA 30, 1992. In: *NFPA 30.* s.l.:s.n.

NFPA 921, 2004. In: *NFPA 921.* s.l.:s.n., p. 15.

PerMen, M. T. K. d. T. R. I., 1980. SYARAT-SYARAT PEMASANGAN DAN PEMELIHARAN ALAT PEMADAM API RINGAN.. In: Jakarta: PerMen, pp. 1-10.

PTK, P. T. K., 2016. Berita Acara. *SPOB Kapuas mengalami kecelakaan*, 25 April.

PTK, P. T. K., 2016. *Sea-web, Ship Detail SPOB Kapuas*. s.l.:s.n.

SOLAS, 2004. *Chapter II-2 Construction – Fire protection, fire detection and fire extinction*. London: IMO.

SOLAS, 2004. *Chapter III Description of Life Saving equipment*. London: IMO.

Spruce, H., 2016. *the hub - highspeedtraining*. [Online] Available at: http://www.highspeedtraining.co.uk/hub/fire-triangle-tetrahedron-combustion/
[Accessed Monday 04 2017].

TechnoKontrol, 2017. *TechnoKontrol*. [Online] Available at: http://www.technokontrol.com/en/products/refinery-en.php [Accessed 09 April 2017].

Transmigrasi, M. T. K. d., 1980. Chaper I. In: Indonesia: s.n., p. 2.1.

Wahono, E., 2008. *Analisis Sistem Fire RollerShutter Terhadap Tingkat Keselamatan Bangunan PasarDengan Simulasi Komputer*. depok: Universitas Indonesia.

# APPENDIX

*"This page intentionally blank"*

# APPENDIX 1
# Apollo Root Cause Analysis - RealityCharting

*“This page intentionally blank”*

# Apollo Root Cause Analysis – RealityCharting Attachment

## 1. General

Apollo Root Cause Analysis – RealityCharting is used in this thesis. ARCA is recommended for event / Incident-based items of complex and higher significance. To complete the apollo root cause analysis, there are 4 steps that should followed. Four steps that should followed are:

1. Define the problem.
   - What, When, and Where.
   - Significant: Safety, Environmental, Cost, etc.
   - Frequency of the problem.
2. Create chart (Reality or Cause-Effect Chart). Chart is created supported with evidence.
   - Iterative process.
   - Look for an appropriate end to each part.
3. Identify possible effective solution.
   - Brainstorm.
   - Not just the favorite solution.
4. Implement best solution and Finalize the report.
   - Complete correction action.

## 2. Define Problem

Define the problem is the first step in Apollo Root Cause Analysis methods. At this stage, every detail of the problems will be explained, who will analyze the problem, an important note in the problem, the source of the data (reference), etc. In this case, the problem of definition of RealityCharting application are explained in Figure 1.

Then proceed to fill in the information about team members. Team members are those who would analyze the problems proficiency level. On Figure 2 will explain how your team members on a charging visualization RealityCharting application, as follows:

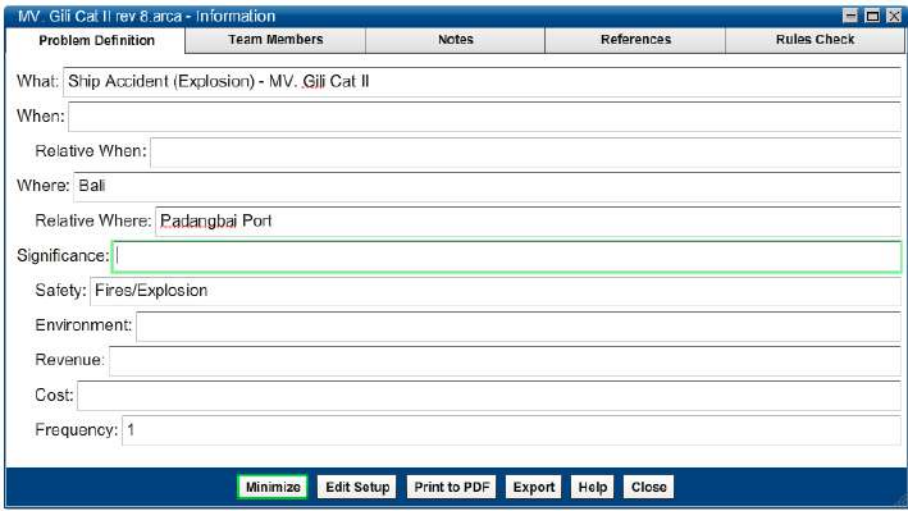



*Figure 1 Problem Definition*

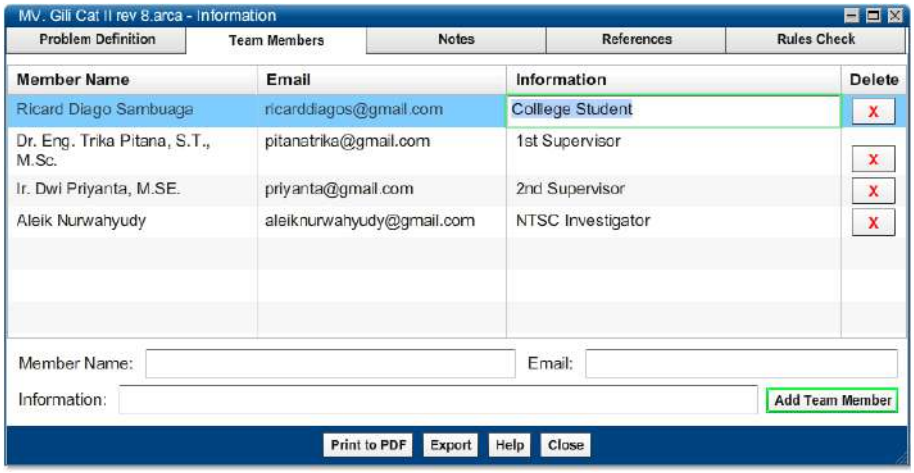



*Figure 2 Team members*

The next stage is to fill an important note of this case. After fill an important note, so next step was filling reference. Figure 3 will explain about visualization to fill a RealityCharting reference on the application, as follows. As you create your chart, the software automatically Identifies the which causes are affected by the rule violations and will probably need further work.

Figure 4 will explain how your visualization of RealityCharting rules check on the application, as follows. After rules check process has been completed and every rule check status has passed so all define problem

stages has been completed. It will proceed with the next step which is to the create chart.

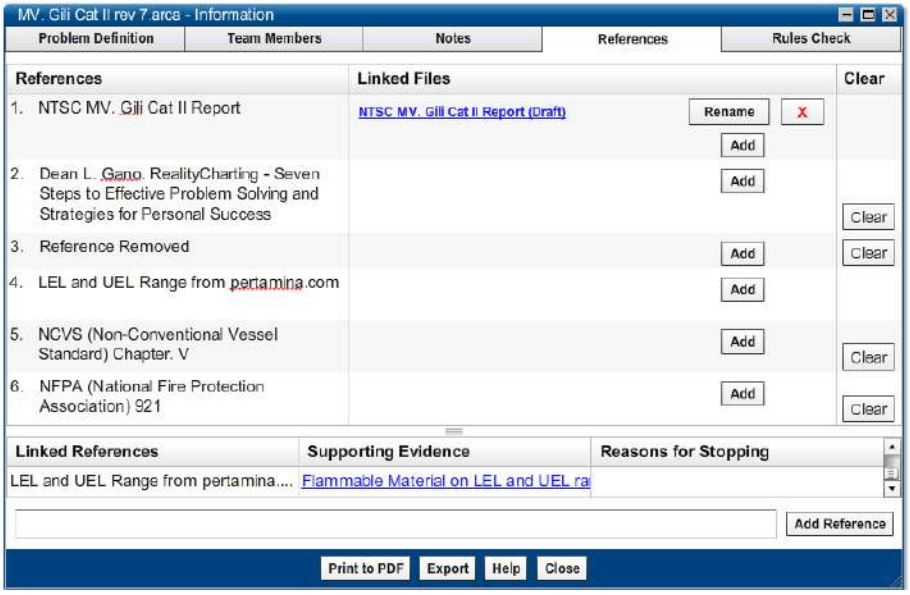



*Figure 3 References*

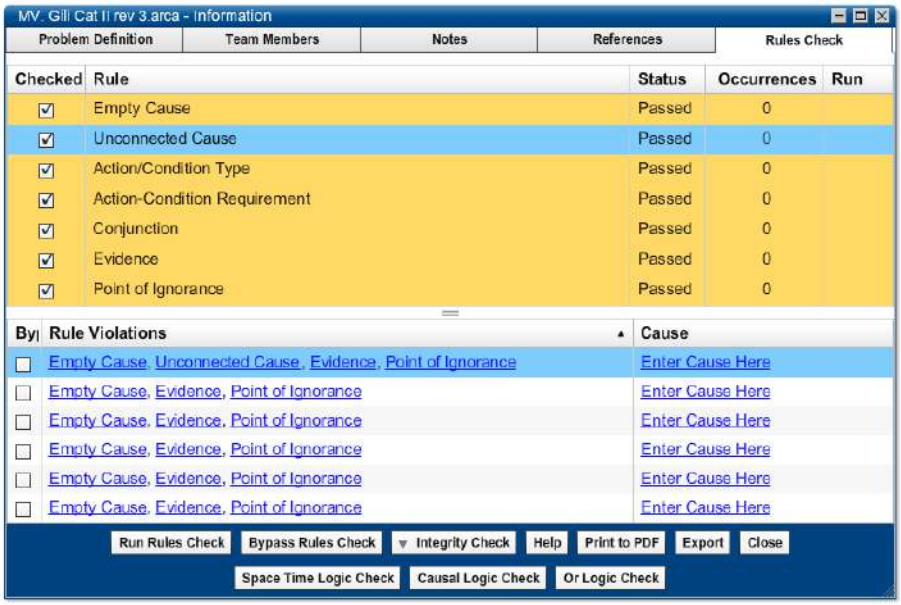



*Figure 4 Rules Check*

## 3. Creating Chart

Create chart is the second step in performing of apollo root cause analysis method. There is an important thing in creating chart of ARCA methods. Each chart should be supported by an evidence. Numbering of each chart is useful for reading the chart. In Figure 5, Figure 6, and Figure 7 are described about numbering of each chart in this case. Detail root cause chart is described in *Root Cause chart.*

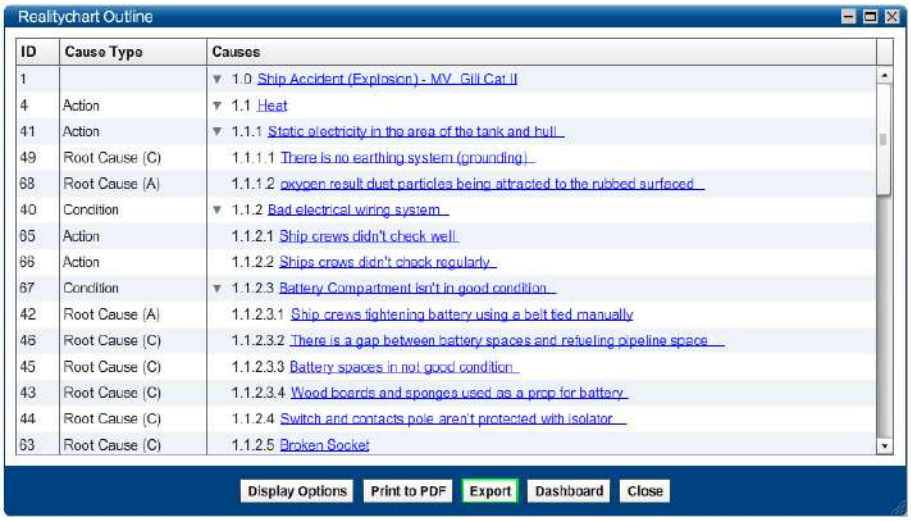



*Figure 5 Outline (Numbering) 1*

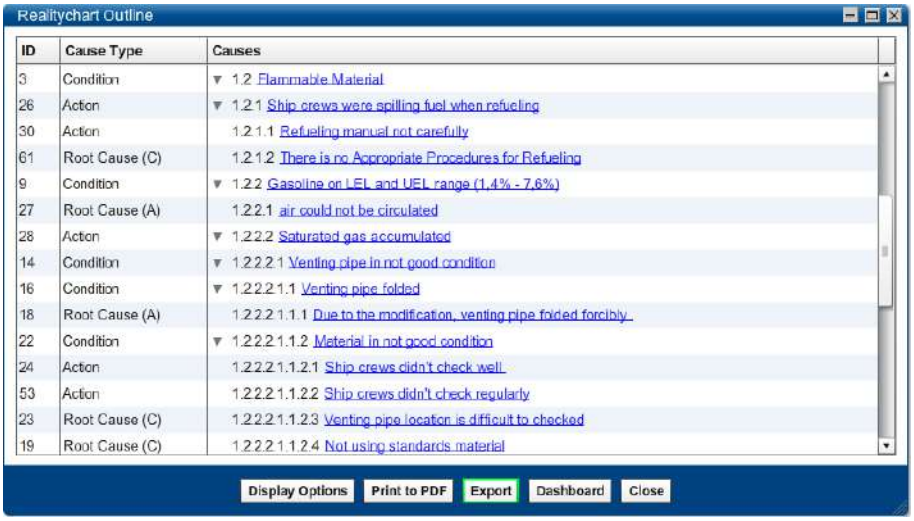



*Figure 6 Outline (Numbering) 2*


*Figure 7 Outline (Numbering) 3*

## 4. Identify Possible Solution

Identify Possible Effective Solution is a phase that we must follow to continue after creating chart. At this stage, team members will identify any effective solution that can be recommended. In recommending solutions in Apollo root cause analysis methods, there are several criteria check. The criteria check are described in Figure 8, In MV. Gili Cat II explosions, there are some recommendations solution that can be implemented solution. MV. Gili Cat II solution recommendations described in Figure 9, as follows:

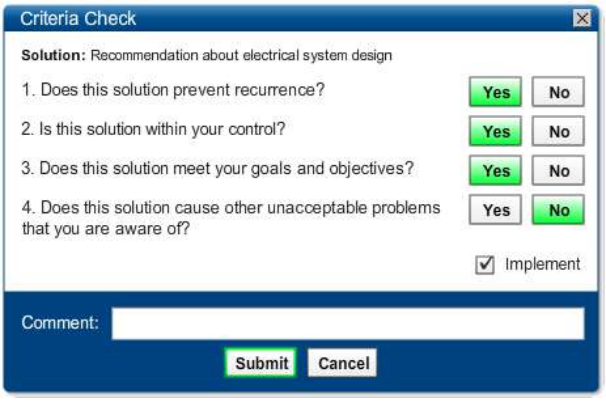



*Figure 8 Criteria Check*

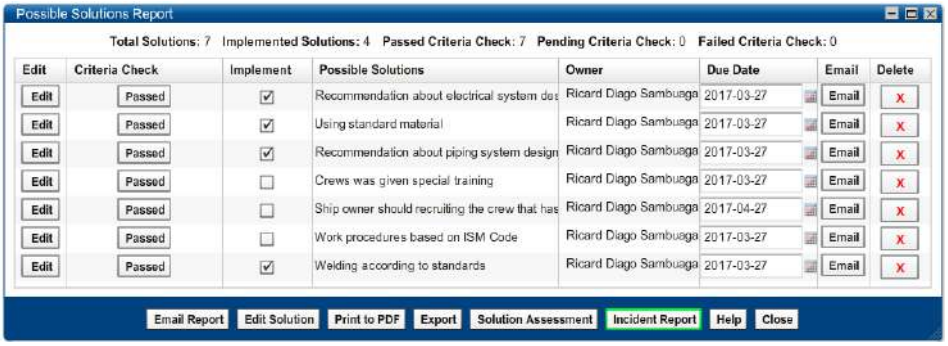



*Figure 9 Recommendation Possible Solution*

## 5. Implementing Best Solution

Implement best solution is the stage where members choose the best solutions that have been recommended. In the solution assessment, there are several criteria. In conducting this assessment, there are several examples of criteria, such as the Figure 10 as follows:

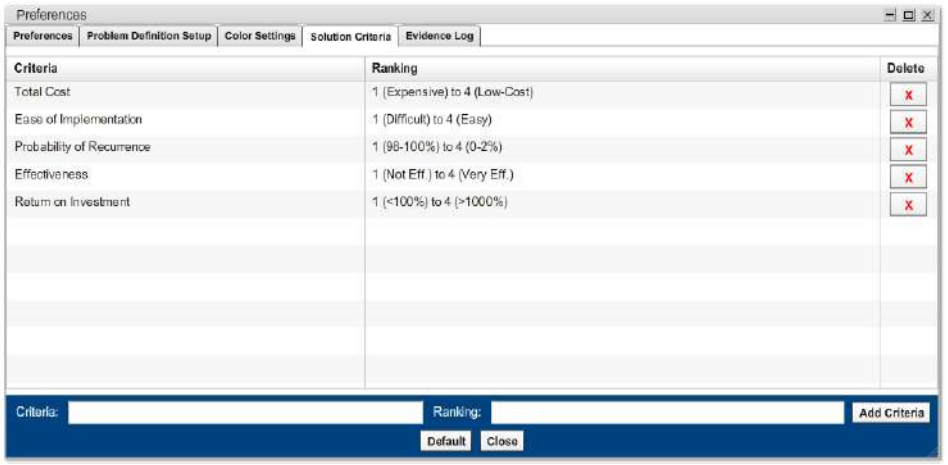



*Figure 10 Solution Criteria Example*

But not all of the criteria I use in this solution assessment. Solution assessment example that I have done in this method is as follows as at Figure 11.


*Figure 11 Solution Assessment Example*

## 6. Finalizing the report

Finalize report is the last stage in the completion of Apollo Root Cause Analysis method. In the RealityCharting software, report creation process will be completed automatically. Here is the result of any incident report on the application RealityCharting. Finalize report described in Appendix 2.

*"This page intentionally blank"*

# APPENDIX 2
# MV. GILI CAT II FINAL REPORT

*“This page intentionally blank”*

# Final Report of MV. Gili Cat II

## Realitychart Dashboard

| REALITYCHART DATA | QUANTITY |
|---|---|
| CAUSES | 46 |
| ACTIONS | 17 |
| CONDITIONS | 29 |
| UNDEFINED CAUSE TYPE | 0 |
| CAUSAL ELEMENTS | 16 |
| OR LOGIC USED | 2 |
| GO TO CONNECTIONS | 0 |
| POSSIBLE SOLUTIONS | 7 |
| PASSED CRITERIA CHECK, NOT IMPLEMENTED | 3 |
| PASSED CRITERIA CHECK, IMPLEMENTED | 4 |
| FAILED CRITERIA CHECK | 0 |
| WAITING FOR CRITERIA CHECK | 0 |
| ACTION ITEMS | 6 |
| FIND EVIDENCE | 0 |
| FIND CAUSES | 6 |
| OTHER | 0 |
| CAUSE PATH ENDINGS | 31 |
| DESIRED CONDITION | 7 |
| LACK OF CONTROL | 17 |
| NEW PRIMARY EFFECT | 1 |
| OTHER CAUSE PATHS MORE PRODUCTIVE | 0 |
| OTHER | 0 |
| NEED MORE INFORMATION | 6 |
| REFERENCED REASON FOR STOPPING | 0 |
| TEAM MEMBERS | 4 |
| RICARD DIAGO SAMBUAGA | |
| ASSIGNED SOLUTIONS | 7 |
| ASSIGNED ACTION ITEMS | 0 |
| DR. ENG. TRIKA PITANA, S.T., M.SC. | |
| ASSIGNED SOLUTIONS | 0 |
| ASSIGNED ACTION ITEMS | 0 |
| IR. DWI PRIYANTA, M.SE. | |
| ASSIGNED SOLUTIONS | 0 |

| | |
|---|---|
| **ASSIGNED ACTION ITEMS** | 0 |
| **FILE LAST SAVED** | Jul. 24, 2017 8:55 PM |
| **FILE VERSION** | 7.5.12110 |

REALITYCHART RULES CHECK

| RULE | STATUS | OCCURRENCES |
|---|---|---|
| **EMPTY CAUSE** | Passed | 0 |
| **UNCONNECTED CAUSE** | Passed | 0 |
| **ACTION/CONDITION TYPE** | Passed | 0 |
| **ACTION-CONDITION REQUIREMENT** | Passed | 3 |
| **CONJUNCTION** | Passed | 7 |
| **EVIDENCE** | Passed | 0 |
| **POINT OF IGNORANCE** | Passed | 0 |

| RULE VIOLATIONS | CAUSE |
|---|---|
| **CONJUNCTION** | Static electricity in the area of the tank and hull |
| **CONJUNCTION** | There is a gap between battery spaces and refueling pipeline space |
| **CONJUNCTION** | Wood boards and sponges used as a prop for battery |
| **CONJUNCTION** | Switch and contacts pole aren't protected with isolator |
| **CONJUNCTION** | Ship crews were spilling fuel when refueling |
| **CONJUNCTION** | There is no Appropriate Procedures for Refueling |
| **CONJUNCTION** | Gasoline on LEL and UEL range (1,4% - 7,6%) |
| **ACTION-CONDITION REQUIREMENT** | Saturated gas accumulated |
| **ACTION-CONDITION REQUIREMENT** | Venting pipe in not good condition |
| **ACTION-CONDITION REQUIREMENT** | No gastight compartment |

## References

| REFERENCES | LINKED FILES |
|---|---|
| 1. **NTSC MV. GILI CAT II REPORT** | NTSC MV. Gili Cat II Report (Draft) |
| 2. **DEAN L. GANO. REALITYCHARTING - SEVEN STEPS TO EFFECTIVE PROBLEM** | |

| REFERENCES | LINKED FILES |
|---|---|
| **SOLVING AND STRATEGIES FOR PERSONAL SUCCESS** | |
| **3. REFERENCE REMOVED** | |
| **4. LEL AND UEL RANGE FROM PERTAMINA.COM** | |
| **5. NCVS (Non-Conventional Vessel Standard) CHAPTER. V** | |
| **6. NFPA (NATIONAL FIRE PROTECTION ASSOCIATION) 921** | |

| LINKED REFERENCES | SUPPORTING EVIDENCE | REASONS FOR STOPPING |
|---|---|---|
| **NTSC MV. GILI CAT II REPORT** | • Bad electrical wiring system<br>• Static electricity in the area of the tank and hull<br>• There is no earthing system<br>• There is a fuel spill when refueling<br>• Refueling pipe in not good condition<br>• No watertight compartment<br>• Tightening battery using a belt tied manually<br>• Wood boards and sponges used as a prop for battery<br>• Switch and contacts pole aren't protected with isolator<br>• Battery spaces in not good condition<br>• There is a gap between battery spaces and refueling pipeline space<br>• Refueling manual not carefully<br>• Lack of air circulation (saturated gas)<br>• Saturated gas accumulated<br>• Sounding pipe is closed and no longer used | |

| LINKED REFERENCES | SUPPORTING EVIDENCE | REASONS FOR STOPPING |
|---|---|---|
| | • Bad electrical wiring system<br>• Static electricity in the area of the tank and hull<br>• There is no earthing system (grounding)<br>• Ship crews were spilling fuel when refueling<br>• Refueling pipe in not good condition<br>• No gastight compartment<br>• Ship crews tightening battery using a belt tied manually<br>• Wood boards and sponges used as a prop for battery<br>• Switch and contacts pole aren't protected with isolator<br>• Battery spaces in not good condition<br>• There is a gap between battery spaces and refueling pipeline space<br>• Refueling manual not carefully<br>• Air could not be circulated<br>• Saturated gas accumulated<br>• Sounding pipe is closed and no longer used<br>• Not using standards material<br>• Connection between hull wrang not exhaustive<br>• Welding on the deck only using spot welding<br>• Venting pipe in not good condition<br>• Venting pipe mounting moved position<br>• Venting pipe connection in not good condition | |

| LINKED REFERENCES | SUPPORTING EVIDENCE | REASONS FOR STOPPING |
|---|---|---|
| | • Venting pipe folded<br>• Venting pipe is easily removable<br>• Plastic pipe is inserted between two pipe connections<br>• There is an insulation tape blocking the hole in the pipe connection<br>• Due to the modification, venting pipe folded forcibly<br>• Material in not good condition<br>• Venting pipe location is difficult to checked<br>• Lack of appropriate pipeline<br>• Not using standards material<br>• There is no venting pipe in compartment beside tank<br>• Battery Compartment isn't in good condition<br>• Oxygen result dust particles being attracted to the rubbed surfaced | |
| **LEL AND UEL RANGE FROM PERTAMINA.COM** | • Gasoline on LEL and UEL range (1,4% - 7,6%) | |

## Notes

| NOTES | LINKED CAUSES |
|---|---|
| 1. **REALITYCHART STATUS: THE INCIDENT REPORT HAS BEEN FINALIZED AND THE REALITYCHART CONTAINS ONE OR MORE RULE VIOLATIONS.** | |
| 2. **RULES CHECK STATUS: SOME CAUSES HAVE BEEN PURPOSEFULLY LEFT OFF THE REALITYCHART.** | |
| 3. **RULES CHECK STATUS: SOME CAUSE PHRASES CONTAIN** | |

| | |
|---|---|
| **CONJUNCTIONS AND MAY REPRESENT MULTIPLE CAUSES.** | |

## Team Members

| MEMBER NAME | EMAIL | INFORMATION |
|---|---|---|
| **RICARD DIAGO SAMBUAGA** | ricarddiagos@gmail.com | Colllege Student |
| **DR. ENG. TRIKA PITANA, S.T., M.SC.** | pitanatrika@gmail.com | 1st Supervisor |
| **IR. DWI PRIYANTA, M.SE.** | priyanta@gmail.com | 2nd Supervisor |
| **ALEIK NURWAHYUDY** | aleiknurhayudy@gmail.com | NTSC Investigator |

## Problem Definition

| Problem Definition |
|---|
| What: Ship Accident (Explosion) - MV. Gili Cat II |
| When: |
| Date: September 15th 2016 |
| Time: 09:30 GMT+08:00 |
| Where: Bali |
| Location: Padangbai Port, Bali |
| Significance: |
| Safety: Fires/Explosion |
| Environment: |
| Revenue: |
| Cost: |
| Frequency: 1 |

## Realitychart Outline

| ID | CAUSE TYPE | CAUSES |
|---|---|---|
| **1** | | 1.0 Ship Accident (Explosion) - MV. Gili Cat II |
| **4** | Action | 1.1 Heat |
| **41** | Action | 1.1.1 Static electricity in the area of the tank and hull |
| **49** | Root Cause (C) | 1.1.1.1 There is no earthing system (grounding) |
| **68** | Root Cause (A) | 1.1.1.2 oxygen result dust particles being attracted to the rubbed surfaced |
| **40** | Condition | 1.1.2 Bad electrical wiring system |
| **65** | Action | 1.1.2.1 Ship crews didn't check well |
| **66** | Action | 1.1.2.2 Ships crews didn't check regularly |
| **67** | Condition | 1.1.2.3 Battery Compartment isn't in good condition |
| **42** | Root Cause (A) | 1.1.2.3.1 Ship crews tightening battery using a belt tied manually |
| **46** | Root Cause (C) | 1.1.2.3.2 There is a gap between battery spaces and refueling pipeline space |
| **43** | Root Cause (C) | 1.1.2.3.3 Wood boards and sponges used as a prop for battery |
| **45** | Root Cause (C) | 1.1.2.3.4 Battery spaces in not good condition |

| ID | CAUSE TYPE | CAUSES |
|---|---|---|
| **44** | Root Cause (C) | 1.1.2.4 Switch and contacts pole aren't protected with isolator |
| **63** | Root Cause (C) | 1.1.2.5 Broken Socket |
| **3** | Condition | 1.2 Flammable Material |
| **26** | Action | 1.2.1 Ship crews were spilling fuel when refueling |
| **30** | Action | 1.2.1.1 Refueling manual not carefully |
| **61** | Root Cause (C) | 1.2.1.2 There is no Appropriate Procedures for Refueling |
| **9** | Condition | 1.2.2 Gasoline on LEL and UEL range (1,4% - 7,6%) |
| **27** | Root Cause (A) | 1.2.2.1 air could not be circulated |
| **28** | Action | 1.2.2.2 Saturated gas accumulated |
| **14** | Condition | 1.2.2.2.1 Venting pipe in not good condition |
| **16** | Condition | 1.2.2.2.1.1 Venting pipe folded |
| **18** | Root Cause (A) | 1.2.2.2.1.1.1 Due to the modification, venting pipe folded forcibly |
| **22** | Condition | 1.2.2.2.1.1.2 Material in not good condition |
| **24** | Action | 1.2.2.2.1.1.2.1 Ship crews didn't check well |
| **53** | Action | 1.2.2.2.1.1.2.2 Ship crews didn't check regularly |
| **23** | Root Cause (C) | 1.2.2.2.1.1.2.3 Venting pipe location is difficult to checked |
| **19** | Root Cause (C) | 1.2.2.2.1.1.2.4 Not using standards material |
| **20** | Root Cause (C) | 1.2.2.2.1.1.3 Lack of appropriate pipeline |
| **15** | Condition | 1.2.2.2.1.2 Venting pipe connection in not good condition |
| **37** | Action | 1.2.2.2.1.2.1 Venting pipe is easily removable |
| **38** | Root Cause (C) | 1.2.2.2.1.2.2 Plastic pipe is inserted between two pipe connections |
| **39** | Root Cause (C) | 1.2.2.2.1.2.3 There is an insulation tape blocking the hole in the pipe connection |
| **13** | Root Cause (C) | 1.2.2.2.2 Venting pipe mounting moved position |
| **60** | Root Cause (C) | 1.2.2.2.3 There is no venting pipe in compartment beside tank |
| **47** | Root Cause (C) | 1.2.2.3 No fuel indicator on tank |

| ID | CAUSE TYPE | CAUSES |
|---|---|---|
| **11** | Condition | 1.2.3 Refueling pipe in not good condition |
| **33** | Action | 1.2.3.1 Ship crews didn't check well |
| **52** | Action | 1.2.3.2 Ship crews didn't check regularly |
| **34** | Root Cause (C) | 1.2.3.3 Not using standards material |
| **2** | Condition | 1.3 Oxygen |
| **6** | Root Cause (A) | 1.3.1 Air come into compartment under deck |
| **5** | Condition | 1.3.2 No gastight compartment |
| **7** | Root Cause (C) | 1.3.2.1 Connection between hull wrang not exhaustive. |
| **8** | Root Cause (C) | 1.3.2.2 Welding on the deck only using spot welding |

RealityCharting Report
For Internal Use Only

Report Date: 2017-03-26
Start Date: 2017-03-20
Report Number: 2

## I. Problem Definition

What: Ship Accident (Explosion) - MV. Gili Cat II
Date: September 15th 2016
Time: 09:30 GMT + 08:00
Where: Bali
Location: Padangbai Port, Bali
Safety: Fires/Explosion
Frequency: 1

## II. Report Summary

1. Ship Accident (Explosion) - MV. Gili Cat II caused by Match Strike and Flammable Material and Oxygen. Flammable Material caused by There is a fuel spill when refueling and Flammable Material on LEL and UEL range and Refueling pipe in not good condition and No fuel indicator on tank. Flammable Material on LEL and UEL range caused by Lack of air circulation (saturated gas) and Saturated gas accumulated. Saturated gas accumulated caused by Venting pipe in not good

condition and Venting pipe mounting moved position. Venting pipe in not good condition caused by Venting pipe connection in not good condition and Venting pipe folded. Venting pipe connection in not good condition caused by Easily removable and Plastic pipe is inserted between two pipe connections and There is an insulation tape blocking the hole in the pipe connection. Solution applied to Plastic pipe is inserted between two pipe connections is Using standard material owned by Ricard Diago Sambuaga and due on 2017-03-27.

2. Ship Accident (Explosion) - MV. Gili Cat II caused by Match Strike and Flammable Material and Oxygen. Flammable Material caused by There is a fuel spill when refueling and Flammable Material on LEL and UEL range and Refueling pipe in not good condition and No fuel indicator on tank. No fuel indicator on tank caused by Sounding pipe is closed and no longer used. Solution applied to Sounding pipe is closed and no longer used is Recommendation about piping system design owned by Ricard Diago Sambuaga and due on 2017-03-27.

3. Ship Accident (Explosion) - MV. Gili Cat II caused by Match Strike and Flammable Material and Oxygen. Flammable Material caused by There is a fuel spill when refueling and Flammable Material on LEL and UEL range and Refueling pipe in not good condition and No fuel indicator on tank. Flammable Material on LEL and UEL range caused by Lack of air circulation (saturated gas) and Saturated gas accumulated. Saturated gas accumulated caused by Venting pipe in not good condition and Venting pipe mounting moved position. Venting pipe in not good condition caused by Venting pipe connection in not good condition and Venting pipe folded. Venting pipe folded caused by Due to the modification, venting pipe folded forcibly. and Material in not good condition and Lack of appropriate pipeline. Solution applied to Due to the modification, venting pipe folded forcibly. is Recommendation about piping system design owned by Ricard Diago Sambuaga and due on 2017-03-27. Solution applied to Due to the modification, venting pipe folded forcibly. is Using standard material owned by Ricard Diago Sambuaga and due on
2017-03-27.

4. Ship Accident (Explosion) - MV. Gili Cat II caused by Match Strike and Flammable Material and Oxygen. Match Strike caused by Bad electrical wiring system and Static electricity in the area of the tank and hull and Lack of ship grounding. Bad electrical wiring system caused by Tightening battery using a belt tied manually and Wood boards and sponges used as a prop for battery and Switch and contacts pole

aren't protected with isolator and Battery spaces in not good condition and There is a gap between battery spaces and refueling pipeline space.. Solution applied to Wood boards and sponges used as a prop for battery is Using standard material owned by Ricard Diago Sambuaga and due on 2017-03-27. Solution applied to Wood boards and sponges used as a prop for battery is Recommendation about electrical system design owned by Ricard Diago Sambuaga and due on 2017-03-27.

5. Ship Accident (Explosion) - MV. Gili Cat II caused by Match Strike and Flammable Material and Oxygen. Match Strike caused by Bad electrical wiring system and Static electricity in the area of the tank and hull and Lack of ship grounding. Solution applied to Lack of ship grounding is Recommendation about electrical system design owned by Ricard Diago Sambuaga and due on 2017-03-27.

6. Ship Accident (Explosion) - MV. Gili Cat II caused by Match Strike and Flammable Material and Oxygen. Match Strike caused by Bad electrical wiring system and Static electricity in the area of the tank and hull and Lack of ship grounding. Bad electrical wiring system caused by Tightening battery using a belt tied manually and Wood boards and sponges used as a prop for battery and Switch and contacts pole aren't protected with isolator and Battery spaces in not good condition and There is a gap between battery spaces and refueling pipeline space. Solution applied to Tightening battery using a belt tied manually is Recommendation about electrical system design owned by Ricard Diago Sambuaga and due on
2017-03-27.

7. Ship Accident (Explosion) - MV. Gili Cat II caused by Match Strike and Flammable Material and Oxygen. Flammable Material caused by There is a fuel spill when refueling and Flammable Material on LEL and UEL range and Refueling pipe in not good condition and No fuel indicator on tank. Flammable Material on LEL and UEL range caused by Lack of air circulation (saturated gas) and Saturated gas accumulated. Saturated gas accumulated caused by Venting pipe in not good condition and Venting pipe mounting moved position. Venting pipe in not good condition caused by Venting pipe connection in not good condition and Venting pipe folded. Solution applied to Venting pipe connection in not good condition is Using standard material owned by Ricard Diago Sambuaga and due on 2017-03-27.

8. Ship Accident (Explosion) - MV. Gili Cat II caused by Match Strike and Flammable Material and Oxygen. Flammable Material caused by There is a fuel spill when refueling and Flammable Material on LEL and UEL range and Refueling pipe in not

good condition and No fuel indicator on tank. Flammable Material on LEL and UEL range caused by Lack of air circulation (saturated gas) and Saturated gas accumulated. Saturated gas accumulated caused by Venting pipe in not good condition and Venting pipe mounting moved position. Venting pipe in not good condition caused by Venting pipe connection in not good condition and Venting pipe folded. Venting pipe folded caused by Due to the modification, venting pipe folded forcibly. and Material in not good condition and Lack of appropriate pipeline. Material in not good condition caused by Ship crews didn't check well and Ship crews didn't check regularly and Venting pipe location is difficult to checked and Not using standards material. Solution applied to Venting pipe location is difficult to checked is Recommendation about piping system design owned by Ricard Diago Sambuaga and due on 2017-03-27. Solution applied to Venting pipe location is difficult to checked is Using standard material owned by Ricard Diago Sambuaga and due on 2017-03-27.

9. Ship Accident (Explosion) - MV. Gili Cat II caused by Match Strike and Flammable Material and Oxygen. Flammable Material caused by There is a fuel spill when refueling and Flammable Material on LEL and UEL range and Refueling pipe in not good condition and No fuel indicator on tank. Flammable Material on LEL and UEL range caused by Lack of air circulation (saturated gas) and Saturated gas accumulated. Saturated gas accumulated caused by Venting pipe in not good condition and Venting pipe mounting moved position. Venting pipe in not good condition caused by Venting pipe connection in not good condition and Venting pipe folded. Venting pipe folded caused by Due to the modification, venting pipe folded forcibly. and Material in not good condition and Lack of appropriate pipeline. Material in not good condition caused by Ship crews didn't check well and Ship crews didn't check regularly and Venting pipe location is difficult to checked and Not using standards material. Solution applied to Not using standards material is Using standard material owned by Ricard Diago Sambuaga and due on 2017-03-27.

10. Ship Accident (Explosion) - MV. Gili Cat II caused by Match Strike and Flammable Material and Oxygen. Flammable Material caused by There is a fuel spill when refueling and Flammable Material on LEL and UEL range and Refueling pipe in not good condition and No fuel indicator on tank. Flammable Material on LEL and UEL range caused by Lack of air circulation (saturated gas) and Saturated gas accumulated. Saturated gas accumulated caused by Venting pipe in not good condition and Venting pipe mounting moved position. Venting pipe in not good condition caused by Venting pipe connection in not good condition and Venting

pipe folded. Solution applied to Venting pipe folded is Recommendation about piping system design owned by Ricard Diago Sambuaga and due on 2017-03-27. Solution applied to Venting pipe folded is Using standard material owned by Ricard Diago Sambuaga and due on 2017-03-27.

11. Ship Accident (Explosion) - MV. Gili Cat II caused by Match Strike and Flammable Material and Oxygen. Match Strike caused by Bad electrical wiring system and Static electricity in the area of the tank and hull and Lack of ship grounding. Bad electrical wiring system caused by Tightening battery using a belt tied manually and Wood boards and sponges used as a prop for battery and Switch and contacts pole aren't protected with isolator and Battery spaces in not good condition and There is a gap between battery spaces and refueling pipeline space. Solution applied to Switch and contacts pole aren't protected with isolator is Recommendation about electrical system design owned by Ricard Diago Sambuaga and due on 2017-03-27.

12. Ship Accident (Explosion) - MV. Gili Cat II caused by Match Strike and Flammable Material and Oxygen. Flammable Material caused by There is a fuel spill when refueling and Flammable Material on LEL and UEL range and Refueling pipe in not good condition and No fuel indicator on tank. Flammable Material on LEL and UEL range caused by Lack of air circulation (saturated gas) and Saturated gas accumulated. Saturated gas accumulated caused by Venting pipe in not good condition and Venting pipe mounting moved position. Solution applied to Venting pipe mounting moved position is Recommendation about piping system design owned by Ricard Diago Sambuaga and due on 2017-03-27. Solution applied to Venting pipe mounting moved position is Using standard material owned by Ricard Diago Sambuaga and due on 2017-03-27.

13. Ship Accident (Explosion) - MV. Gili Cat II caused by Match Strike and Flammable Material and Oxygen. Oxygen caused by Air come into compartment under deck and No watertight compartment. No watertight compartment caused by Connection between hull wrang not exhaustive. and Welding on the deck only using spot welding. Solution applied to Connection between hull wrang not exhaustive. is Welding according to standards owned by Ricard Diago Sambuaga and due on 2017-03-27.

14. Ship Accident (Explosion) - MV. Gili Cat II caused by Match Strike and Flammable Material and Oxygen. Oxygen caused by Air come into compartment under deck and No watertight compartment. Solution applied to Air come into compartment

under deck is Welding according to standards owned by Ricard Diago Sambuaga and due on 2017-03-27.

15. Ship Accident (Explosion) - MV. Gili Cat II caused by Match Strike and Flammable Material and Oxygen. Flammable Material caused by There is a fuel spill when refueling and Flammable Material on LEL and UEL range and Refueling pipe in not good condition and No fuel indicator on tank. Solution applied to No fuel indicator on tank is Recommendation about piping system design owned by Ricard Diago Sambuaga and due on 2017-03-27.

16. Ship Accident (Explosion) - MV. Gili Cat II caused by Match Strike and Flammable Material and Oxygen. Flammable Material caused by There is a fuel spill when refueling and Flammable Material on LEL and UEL range and Refueling pipe in not good condition and No fuel indicator on tank. Flammable Material on LEL and UEL range caused by Lack of air circulation (saturated gas) and Saturated gas accumulated. Saturated gas accumulated caused by Venting pipe in not good condition and Venting pipe mounting moved position. Venting pipe in not good condition caused by Venting pipe connection in not good condition and Venting pipe folded. Venting pipe folded caused by Due to the modification, venting pipe folded forcibly. and Material in not good condition and Lack of appropriate pipeline. Solution applied to Material in not good condition is Using standard material owned by Ricard Diago Sambuaga and due on 2017-03-27.

17. Ship Accident (Explosion) - MV. Gili Cat II caused by Match Strike and Flammable Material and Oxygen. Match Strike caused by Bad electrical wiring system and Static electricity in the area of the tank and hull and Lack of ship grounding. Bad electrical wiring system caused by Tightening battery using a belt tied manually and Wood boards and sponges used as a prop for battery and Switch and contacts pole aren't protected with isolator and Battery spaces in not good condition and There is a gap between battery spaces and refueling pipeline space. Solution applied to Battery spaces in not good condition is Recommendation about electrical system design owned by Ricard Diago Sambuaga and due on 2017-03-27.

18. Ship Accident (Explosion) - MV. Gili Cat II caused by Match Strike and Flammable Material and Oxygen. Match Strike caused by Bad electrical wiring system and Static electricity in the area of the tank and hull and Lack of ship grounding. Bad electrical wiring system caused by Tightening battery using a belt tied manually and Wood boards and sponges used as a prop for battery and Switch and contacts pole aren't protected with isolator and Battery spaces in not good condition and There

is a gap between battery spaces and refueling pipeline space. Solution applied to There is a gap between battery spaces and refueling pipeline space. is Recommendation about electrical system design owned by Ricard Diago Sambuaga and due on 2017-03-27.

19. Ship Accident (Explosion) - MV. Gili Cat II caused by Match Strike and Flammable Material and Oxygen. Flammable Material caused by There is a fuel spill when refueling and Flammable Material on LEL and UEL range and Refueling pipe in not good condition and No fuel indicator on tank. Flammable Material on LEL and UEL range caused by Lack of air circulation (saturated gas) and Saturated gas accumulated. Saturated gas accumulated caused by Venting pipe in not good condition and Venting pipe mounting moved position. Venting pipe in not good condition caused by Venting pipe connection in not good condition and Venting pipe folded. Venting pipe folded caused by Due to the modification, venting pipe folded forcibly. and Material in not good condition and Lack of appropriate pipeline. Solution applied to Lack of appropriate pipeline is Recommendation about piping system design owned by Ricard Diago Sambuaga and due on 2017-03-27.

20. Ship Accident (Explosion) - MV. Gili Cat II caused by Match Strike and Flammable Material and Oxygen. Flammable Material caused by There is a fuel spill when refueling and Flammable Material on LEL and UEL range and Refueling pipe in not good condition and No fuel indicator on tank. Flammable Material on LEL and UEL range caused by Lack of air circulation (saturated gas) and Saturated gas accumulated. Saturated gas accumulated caused by Venting pipe in not good condition and Venting pipe mounting moved position. Venting pipe in not good condition caused by Venting pipe connection in not good condition and Venting pipe folded. Venting pipe connection in not good condition caused by Easily removable and Plastic pipe is inserted between two pipe connections and There is an insulation tape blocking the hole in the pipe connection. Solution applied to There is an insulation tape blocking the hole in the pipe connection is Using standard material owned by Ricard Diago Sambuaga and due on 2017-03-27.

21. Ship Accident (Explosion) - MV. Gili Cat II caused by Match Strike and Flammable Material and Oxygen. Flammable Material caused by There is a fuel spill when refueling and Flammable Material on LEL and UEL range and Refueling pipe in not good condition and No fuel indicator on tank. Flammable Material on LEL and UEL range caused by Lack of air circulation (saturated gas) and Saturated gas accumulated. Solution applied to Lack of air circulation (saturated gas) is

Recommendation about piping system design owned by Ricard Diago Sambuaga and due on 2017-03-27.

22. Ship Accident (Explosion) - MV. Gili Cat II caused by Match Strike and Flammable Material and Oxygen. Flammable Material caused by There is a fuel spill when refueling and Flammable Material on LEL and UEL range and Refueling pipe in not good condition and No fuel indicator on tank. Solution applied to Refueling pipe in not good condition is Recommendation about piping system design owned by Ricard Diago Sambuaga and due on 2017-03-27. Solution applied to Refueling pipe in not good condition is Using standard material owned by Ricard Diago Sambuaga and due on 2017-03-27.

23. Ship Accident (Explosion) - MV. Gili Cat II caused by Match Strike and Flammable Material and Oxygen. Flammable Material caused by There is a fuel spill when refueling and Flammable Material on LEL and UEL range and Refueling pipe in not good condition and No fuel indicator on tank. There is a fuel spill when refueling caused by Refueling manually and Refueling isn't using an appropriate pump. Solution applied to Refueling isn't using an appropriate pump is Recommendation about piping system design owned by Ricard Diago Sambuaga and due on 2017-03-27.

24. Ship Accident (Explosion) - MV. Gili Cat II caused by Match Strike and Flammable Material and Oxygen. Flammable Material caused by There is a fuel spill when refueling and Flammable Material on LEL and UEL range and Refueling pipe in not good condition and No fuel indicator on tank. Refueling pipe in not good condition caused by Ship crews didn't check well and Ship crews didn't check regularly and Not using standards material. Solution applied to Not using standards material is Using standard material owned by Ricard Diago Sambuaga and due on 2017-03-27.

25. Ship Accident (Explosion) - MV. Gili Cat II caused by Match Strike and Flammable Material and Oxygen. Match Strike caused by Bad electrical wiring system and Static electricity in the area of the tank and hull and Lack of ship grounding. Solution applied to Static electricity in the area of the tank and hull is Recommendation about electrical system design owned by Ricard Diago Sambuaga and due on 2017-03-27.

26. Ship Accident (Explosion) - MV. Gili Cat II caused by Match Strike and Flammable Material and Oxygen. Oxygen caused by Air come into compartment under deck and No watertight compartment. No watertight compartment caused by

Connection between hull wrang not exhaustive. and Welding on the deck only using spot welding. Solution applied to Welding on the deck only using spot welding is Welding according to standards owned by Ricard Diago Sambuaga and due on 2017-03-27.

27. Ship Accident (Explosion) - MV. Gili Cat II caused by Match Strike and Flammable Material and Oxygen. Flammable Material caused by There is a fuel spill when refueling and Flammable Material on LEL and UEL range and Refueling pipe in not good condition and No fuel indicator on tank. Solution applied to There is a fuel spill when refueling is Recommendation about piping system design owned by Ricard Diago Sambuaga and due on 2017-03-27.

28. Ship Accident (Explosion) - MV. Gili Cat II caused by Match Strike and Flammable Material and Oxygen. Oxygen caused by Air come into compartment under deck and No watertight compartment. Solution applied to No watertight compartment is Welding according to standards owned by Ricard Diago Sambuaga and due on 2017-03-27.

29. Ship Accident (Explosion) - MV. Gili Cat II caused by Match Strike and Flammable Material and Oxygen. Match Strike caused by Bad electrical wiring system and Static electricity in the area of the tank and hull and Lack of ship grounding. Solution applied to Bad electrical wiring system is Recommendation about electrical system design owned by Ricard Diago Sambuaga and due on 2017-03-27.

## III. Solutions

| ROOT CAUSES | SOLUTIONS | OWNER | DUE DATE |
|---|---|---|---|
| • **SHIP CREWS TIGHTENING BATTERY USING A BELT TIED MANUALLY**<br>• **WOOD BOARDS AND SPONGES USED AS A PROP FOR BATTERY**<br>• **SWITCH AND CONTACTS POLE AREN'T PROTECTED WITH ISOLATOR**<br>• **BATTERY SPACES IN NOT GOOD CONDITION**<br>• **THERE IS A GAP BETWEEN BATTERY SPACES AND REFUELING PIPELINE SPACE**<br>• **THERE IS NO EARTHING SYSTEM (GROUNDING)**<br>• **BROKEN SOCKET** | Recommendation about electrical system design | Ricard Diago Sambuaga | 03/27/2017 |

| ROOT CAUSES | SOLUTIONS | OWNER | DUE DATE |
|---|---|---|---|
| • **OXYGEN RESULT DUST PARTICLES BEING ATTRACTED TO THE RUBBED SURFACED** | | | |
| • **NOT USING STANDARDS MATERIAL**<br>• **NOT USING STANDARDS MATERIAL**<br>• **THERE IS AN INSULATION TAPE BLOCKING THE HOLE IN THE PIPE CONNECTION**<br>• **PLASTIC PIPE IS INSERTED BETWEEN TWO PIPE CONNECTIONS**<br>• **WOOD BOARDS AND SPONGES USED AS A PROP FOR BATTERY**<br>• **DUE TO THE MODIFICATION, VENTING PIPE FOLDED FORCIBLY.** | Using standard material | Ricard Diago Sambuaga | 03/27/2017 |

| ROOT CAUSES | SOLUTIONS | OWNER | DUE DATE |
|---|---|---|---|
| • **VENTING PIPE LOCATION IS DIFFICULT TO CHECKED**<br>• **VENTING PIPE MOUNTING MOVED POSITION** | | | |
| • **VENTING PIPE LOCATION IS DIFFICULT TO CHECKED**<br>• **VENTING PIPE MOUNTING MOVED POSITION**<br>• **LACK OF APPROPRIATE PIPELINE**<br>• **DUE TO THE MODIFICATION, VENTING PIPE FOLDED FORCIBLY.**<br>• **AIR COULD NOT BE CIRCULATED**<br>• **THERE IS NO VENTING PIPE IN COMPARTMENT BESIDE TANK** | Recommendation about piping system design | Ricard Diago Sambuaga | 03/27/2017 |

| ROOT CAUSES | SOLUTIONS | OWNER | DUE DATE |
|---|---|---|---|
| • **THERE IS NO APPROPRIATE PROCEDURES FOR REFUELING**<br>• **NO FUEL INDICATOR ON TANK** | | | |
| • **SHIP CREWS DIDN'T CHECK WELL**<br>• **SHIP CREWS DIDN'T CHECK WELL**<br>• **REFUELING MANUAL NOT CAREFULLY**<br>• **SHIP CREWS WERE SPILLING FUEL WHEN REFUELING**<br>• **SHIP CREWS DIDN'T CHECK REGULARLY**<br>• **SHIP CREWS DIDN'T CHECK REGULARLY**<br>• **THERE IS NO APPROPRIATE PROCEDURES FOR REFUELING** | Crews was given special training | Ricard Diago Sambuaga | 2017-03-27 |
| • **SHIP CREWS DIDN'T CHECK WELL**<br>• **SHIP CREWS DIDN'T CHECK WELL** | Ship owner should recruiting the crew that has been certified | | |

| ROOT CAUSES | SOLUTIONS | OWNER | DUE DATE |
|---|---|---|---|
| • **REFUELING MANUAL NOT CAREFULLY**<br>• **SHIP CREWS DIDN'T CHECK REGULARLY**<br>• **SHIP CREWS DIDN'T CHECK REGULARLY** | | | |
| • **SHIP CREWS DIDN'T CHECK WELL**<br>• **REFUELING MANUAL NOT CAREFULLY**<br>• **SHIP CREWS DIDN'T CHECK WELL**<br>• **SHIP CREWS DIDN'T CHECK REGULARLY**<br>• **SHIP CREWS DIDN'T CHECK REGULARLY** | Work procedures based on ISM Code | | |
| • **WELDING ON THE DECK ONLY USING SPOT WELDING**<br>• **CONNECTION BETWEEN HULL WRANG NOT EXHAUSTIVE.**<br>• **AIR COME INTO COMPARTMENT UNDER DECK** | Welding according to standards | | |

## IV. Team Members

| NAME | EMAIL | INFORMATION |
|---|---|---|
| **RICARD DIAGO SAMBUAGA** | ricarddiagos@gmail.com | Colllege Student |
| **DR. ENG. TRIKA PITANA, S.T., M.SC.** | pitanatrika@gmail.com | 1st Supervisor |
| **IR. DWI PRIYANTA, M.SE.** | priyanta@gmail.com | 2nd Supervisor |
| **ALEIK NURWAHYUDY** | aleiknurwahyudy@gmail.com | NTSC Investigator |

## V. Notes

1. Realitychart Status: The Incident Report has been finalized and the Realitychart contains one or more rule violations.
2. Rules Check Status: Some causes have been purposefully left off the Realitychart.
3. Rules Check Status: Some cause phrases contain conjunctions and may represent multiple causes.

## VI. References

1. NTSC MV. Gili Cat II Report
2. Dean L. Gano. RealityCharting - Seven Steps to Effective Problem Solving and Strategies for Personal Success
3. Reference Removed
4. LEL and UEL Range from pertamina.com
5. NCVS (Non-Conventional Vessel Standard) Chapter V
6. NFPA (National Fire Protection Association) 921

## RealityCharting Action Item Report

| ACTION ITEM | LINKED CAUSES | OWNER | DUE DATE |
|---|---|---|---|
| **FIND OUT WHY** | Connection between hull wrang not exhaustive. | Ricard Diago Sambuaga | |
| **FIND OUT WHY** | Welding on the deck only using spot welding | Ricard Diago Sambuaga | |
| **FIND OUT WHY** | There is an insulation tape blocking the hole | Ricard Diago Sambuaga | |

| ACTION ITEM | LINKED CAUSES | OWNER | DUE DATE |
|---|---|---|---|
| | in the pipe connection | | |
| **FIND OUT WHY** | There is no earthing system (grounding) | Ricard Diago Sambuaga | |
| **FIND OUT WHY** | Not using standards material | Ricard Diago Sambuaga | |
| **FIND OUT WHY** | oxygen result dust particles being attracted to the rubbed surfaced | Ricard Diago Sambuaga | |

## RealityCharting Possible Solutions Report

| SOLUTION | CRITERIA CHECK | IMPLEMENT | OWNER | DUE DATE |
|---|---|---|---|---|
| **RECOMMENDATION ABOUT ELECTRICAL SYSTEM DESIGN** | Passed | Yes | Ricard Diago Sambuaga | 2017-03-27 |

| CAUSE ID | CAUSES |
|---|---|
| **42** | Ship crews tightening battery using a belt tied manually |
| **43** | Wood boards and sponges used as a prop for battery |
| **44** | Switch and contacts pole aren't protected with isolator |
| **45** | Battery spaces in not good condition |
| **46** | There is a gap between battery spaces and refueling pipeline space |
| **49** | There is no earthing system (grounding) |
| **63** | Broken Socket |
| **68** | oxygen result dust particles being attracted to the rubbed surfaced |

| SOLUTION | CRITERIA CHECK | IMPLEMENT | OWNER | DUE DATE |
|---|---|---|---|---|
| **USING STANDARD MATERIAL** | Passed | Yes | Ricard Diago Sambuaga | 2017-03-27 |

| CAUSE ID | CAUSES |
|---|---|
| **19** | Not using standards material |
| **34** | Not using standards material |
| **39** | There is an insulation tape blocking the hole in the pipe connection |

| CAUSE ID | CAUSES |
|---|---|
| **38** | Plastic pipe is inserted between two pipe connections |
| **43** | Wood boards and sponges used as a prop for battery |
| **18** | Due to the modification, venting pipe folded forcibly. |
| **23** | Venting pipe location is difficult to checked |
| **13** | Venting pipe mounting moved position |

| SOLUTION | CRITERIA CHECK | IMPLEMENT | OWNER | DUE DATE |
|---|---|---|---|---|
| **RECOMMENDATION ABOUT PIPING SYSTEM DESIGN** | Passed | Yes | Ricard Diago Sambuaga | 2017-03-27 |

| CAUSE ID | CAUSES |
|---|---|
| **23** | Venting pipe location is difficult to checked |
| **13** | Venting pipe mounting moved position |
| **20** | Lack of appropriate pipeline |
| **18** | Due to the modification, venting pipe folded forcibly. |
| **27** | air could not be circulated |
| **60** | There is no venting pipe in compartment beside tank |
| **61** | There is no Appropriate Procedures for Refueling |
| **47** | No fuel indicator on tank |

| SOLUTION | CRITERIA CHECK | IMPLEMENT | OWNER | DUE DATE |
|---|---|---|---|---|
| **CREWS WAS GIVEN SPECIAL TRAINING** | Passed | No | Ricard Diago Sambuaga | 2017-03-27 |

| CAUSE ID | CAUSES |
|---|---|
| **24** | Ship crews didn't check well |
| **33** | Ship crews didn't check well |
| **30** | Refueling manual not carefully |
| **26** | Ship crews were spilling fuel when refueling |
| **53** | Ship crews didn't check regularly |
| **52** | Ship crews didn't check regularly |
| **61** | There is no Appropriate Procedures for Refueling |

| SOLUTION | CRITERIA CHECK | IMPLEMENT | OWNER | DUE DATE |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| **SHIP OWNER SHOULD RECRUITING THE CREW THAT HAS BEEN CERTIFIED** | Passed | No | Ricard Diago Sambuaga | 2017-04-27 |

| CAUSE ID | CAUSES |
|---|---|
| **24** | Ship crews didn't check well |
| **33** | Ship crews didn't check well |
| **30** | Refueling manual not carefully |
| **53** | Ship crews didn't check regularly |
| **52** | Ship crews didn't check regularly |

| SOLUTION | CRITERIA CHECK | IMPLEMENT | OWNER | DUE DATE |
|---|---|---|---|---|
| **WORK PROCEDURES BASED ON ISM CODE** | Passed | No | Ricard Diago Sambuaga | 2017-03-27 |

| CAUSE ID | CAUSES |
|---|---|
| **24** | Ship crews didn't check well |
| **30** | Refueling manual not carefully |
| **33** | Ship crews didn't check well |
| **52** | Ship crews didn't check regularly |
| **53** | Ship crews didn't check regularly |

| SOLUTION | CRITERIA CHECK | IMPLEMENT | OWNER | DUE DATE |
|---|---|---|---|---|
| **WELDING ACCORDING TO STANDARDS** | Passed | Yes | Ricard Diago Sambuaga | 2017-03-27 |

| CAUSE ID | CAUSES |
|---|---|
| **8** | Welding on the deck only using spot welding |
| **7** | Connection between hull wrang not exhaustive. |
| **6** | Air come into compartment under deck |

## RealityCharting Solution Assessment Report

## Summary

| CRITERIA | CRITERIA | CRITERIA | CRITERIA |
|---|---|---|---|
| **PROBABILITY OF RECURRENCE** | Ease of Implementation | Effectiveness | Total Cost |
| **WEIGHT** | Weight | Weight | Weight |
| **1** | 1 | 1 | 1 |
| **RANKING** | Ranking | Ranking | Ranking |
| **1 (98-100%) TO 4 (0-2%)** | 1 (Difficult) to 4 (Easy) | 1 (Not Eff.) to 4 (Very Eff.) | 1 (Expensive) to 4 (Low-Cost) |

| CAUSE | SOLUTION | COMMENT | CRITERIA (1) | CRITERIA (2) | CRITERIA (3) | CRITERIA (4) |
|---|---|---|---|---|---|---|
| • **BAD ELECTRICAL WIRING SYSTEM**<br>• **TIGHTENING BATTERY USING A BELT TIED MANUALLY**<br>• **WOOD BOARDS AND SPONGES USED AS A PROP FOR BATTERY**<br>• **SWITCH AND CONTACTS POLE AREN'T PROTECTED WITH ISOLATOR**<br>• **BATTERY SPACES IN NOT GOOD CONDITION** | Recommendation about electrical system design | ` | **2,67** | **3,33** | **3,67** | **2,33** |

| CAUSE | SOLUTION | COMMENT | CRITERIA (1) | CRITERIA (2) | CRITERIA (3) | CRITERIA (4) |
|---|---|---|---|---|---|---|
| • **THERE IS A GAP BETWEEN BATTERY SPACES AND REFUELING PIPELINE SPACE.**<br>• **LACK OF SHIP GROUNDING**<br>• **STATIC ELECTRICITY IN THE AREA OF THE TANK AND HULL** | | | | | | |
| • **NOT USING STANDARDS MATERIAL**<br>• **MATERIAL IN NOT GOOD CONDITION**<br>• **NOT USING STANDARDS MATERIAL**<br>• **THERE IS AN INSULATION TAPE BLOCKING THE HOLE IN THE PIPE CONNECTION**<br>• **PLASTIC PIPE IS INSERTED BETWEEN TWO PIPE CONNECTIONS**<br>• **VENTING PIPE CONNECTION IN NOT GOOD CONDITION**<br>• **WOOD BOARDS AND SPONGES USED AS A PROP FOR BATTERY** | Using standard material | | **3,33** | **3,67** | **4,00** | **3,00** |

| CAUSE | SOLUTION | COMMENT | CRITERIA (1) | CRITERIA (2) | CRITERIA (3) | CRITERIA (4) |
|---|---|---|---|---|---|---|
| • **REFUELING PIPE IN NOT GOOD CONDITION**<br>• **VENTING PIPE FOLDED**<br>• **DUE TO THE MODIFICATION, VENTING PIPE FOLDED FORCIBLY**<br>• **VENTING PIPE LOCATION IS DIFFICULT TO CHECKED**<br>• **VENTING PIPE MOUNTING MOVED POSITON** | | | | | | |
| • **VENTING PIPE LOCATION IS DIFFICULT TO CHECKED**<br>• **NO FUEL INDICATOR ON TANK**<br>• **REFUELING PIPE IN NOT GOOD CONDITION**<br>• **VENTING PIPE MOUNTING MOVED POSITON**<br>• **LACK OF APPROPRIATE PIPELINE**<br>• **DUE TO THE MODIFICATION, VENTING PIPE FOLDED FORCIBLY**<br>• **VENTING PIPE FOLDED**<br>• **LACK OF AIR CIRCULATION (SATURATED GAS)** | Recommendation about piping system design | | **3,33** | **3,33** | **4,00** | **2,67** |

| CAUSE | SOLUTION | COMMENT | CRITERIA (1) | CRITERIA (2) | CRITERIA (3) | CRITERIA (4) |
|---|---|---|---|---|---|---|
| • **REFUELING ISN'T USING AN APPROPRIATE PUMP**<br>• **THERE IS A FUEL SPILL WHEN REFUELING**<br>• **SOUNDING PIPE IS CLOSED AND NO LONGER USED** | | | | | | |
| • **SHIP CREWS DIDN'T CHECK WELL**<br>• **SHIP CREWS DIDN'T CHECK WELL**<br>• **REFUELING MANUALLY**<br>• **THERE IS A FUEL SPILL WHEN REFUELING**<br>• **SHIP CREWS DIDN'T CHECK REGULARLY**<br>• **SHIP CREWS DIDN'T CHECK REGULARLY** | Crews was given special training | | **2,67** | **3,67** | **3,33** | **2,67** |
| • **SHIP CREWS DIDN'T CHECK WELL**<br>• **SHIP CREWS DIDN'T CHECK WELL**<br>• **REFUELING MANUALLY**<br>• **SHIP CREWS DIDN'T CHECK REGULARLY**<br>• **SHIP CREWS DIDN'T CHECK REGULARLY** | Ship owner should recruiting the crew that has been certified | | **2,67** | **3,67** | **3,67** | **2,67** |

| CAUSE | SOLUTION | COMMENT | CRITERIA (1) | CRITERIA (2) | CRITERIA (3) | CRITERIA (4) |
|---|---|---|---|---|---|---|
| • **SHIP CREWS DIDN'T CHECK WELL**<br>• **REFUELING MANUALLY**<br>• **SHIP CREWS DIDN'T CHECK WELL**<br>• **SHIP CREWS DIDN'T CHECK REGULARLY**<br>• **SHIP CREWS DIDN'T CHECK REGULARLY** | Work procedures based on ISM Code | | **3,33** | **3,33** | **3,33** | **2,33** |
| • **WELDING ON THE DECK ONLY USING SPOT WELDING**<br>• **CONNECTION BETWEEN HULL WRANG NOT EXHAUSTIVE.**<br>• **NO WATERTIGHT COMPARTEMENT**<br>• **AIR COME INTO COMPARTEMENT UNDER DECK** | Welding according to standards | | **3,33** | **3,00** | **4,00** | **2,33** |

*“This page intentionally blank”*

**Primary Effect**
Ship Accident (Explosion) - MV. Gili Cat II

Caused By

**Action**
Heat

Caused By

OR

**Action**
Static electricity in the area of the tank and hull

Caused By

**Root Cause (C)**
There is no earthing system (grounding)

Caused By

More Info Needed

**Root Cause (A)**
oxygen result dust particles being attracted to the rubbed surfaced

Caused By

More Info Needed

**Condition**
Bad electrical wiring system

Caused By

**Action**
Ship crews didn't check well

Caused By

Lack Of Control

**Action**
Ships crews didn't check regularly

Caused By

Lack Of Control

**Condition**
Battery Compartment isn't in good condition

Caused By

**Root Cause (A)**
Ship crews tightening battery using a belt tied manually

Caused By

Desired Condition

**Root Cause (C)**
There is a gap between battery spaces and refueling pipeline space

Caused By

Lack Of Control

**Root Cause (C)**
Wood boards and sponges used as a prop for battery

Caused By

Desired Condition

**Root Cause (C)**
Battery spaces in not good condition

Caused By

Lack Of Control

**Root Cause (C)**
Switch and contacts pole aren't protected with isolator

Caused By

Lack Of Control

**Root Cause (C)**
Broken Socket

Caused By

Lack Of Control

**Condition**
Flammable Material

Caused By

**Action**
Ship crews were spilling fuel when refueling

Caused By

**Action**
Refueling manual not carefully

Caused By

Lack Of Control

**Root Cause (C)**
There is no Appropriate Procedures for Refueling

Caused By

Lack Of Control

**Root Cause (A)**
air could not be circulated

Caused By

New Primary Effect

**Condition**
Gasoline on LEL and UEL range (1,4% - 7,6%)

Caused By

**Action**
Saturated gas accumulated

Caused By

**Condition**
Venting pipe in not good condition

Caused By

**Condition**
Venting pipe connection in not good condition

Caused By

**Root Cause (A)**
Due to the modification, venting pipe folded forcibly .

Caused By

Desired Condition

**Condition**
Venting pipe folded

Caused By

**Condition**
Material in not good condition

Caused By

**Action**
Ship crews didn't check well

Caused By

Lack Of Control

**Action**
Ship crews didn't check regularly

Caused By

Lack Of Control

**Root Cause (C)**
Venting pipe location is difficult to checked

Caused By

Lack Of Control

**Root Cause (C)**
Not using standards material

Caused By

More Info Needed

**Root Cause (C)**
Lack of appropriate pipeline

Caused By

Lack Of Control

**Action**
Venting pipe is easily removable

Caused By

Lack Of Control

**Root Cause (C)**
Plastic pipe is inserted between two pipe connections

Caused By

Desired Condition

**Root Cause (C)**
There is an insulation tape blocking the hole in the pipe connection

Caused By

More Info Needed

**Root Cause (C)**
Venting pipe mounting moved positon

Caused By

Desired Condition

**Root Cause (C)**
There is no venting pipe in compartment beside tank

Caused By

Desired Condition

**Root Cause (C)**
No fuel indicator on tank

Caused By

Lack Of Control

**Condition**
Refueling pipe in not good condition

Caused By

**Action**
Ship crews didn't check well

Caused By

Lack Of Control

**Action**
Ship crews didn't check regularly

Caused By

Lack Of Control

**Root Cause (C)**
Not using standards material

Caused By

Desired Condition

**Condition**
Oxygen

Caused By

**Root Cause (A)**
Air come into compartement under deck

Caused By

Lack Of Control

**Condition**
No gastight compartement

Caused By

**Root Cause (C)**
Connection between hull wrang not exhaustive.

Caused By

More Info Needed

**Root Cause (C)**
Welding on the deck only using spot welding

Caused By

More Info Needed

# APPENDIX 3
# MV. Gili Cat II Solution Assessment Questionnaire

*“This page intentionally blank”*

**RealityCharting Solution Assessment Report (MV. Gili Cat II)**

## A. Pengantar & Tujuan Kuisioner

Kuisioner ini dibuat untuk mendapatkan data tugas akhir yang digunakan pada studi evaluasi ledakan MV. Gili Cat II. Penilaian yang dilakukan pada setiap solusi yang direkomendasikan. Pengisian kuisinoner dilakukan dengan cara menilai solusi-solusi yang direkomendasikan berdasarkan setiap kriteria yang ada. Kriteria pada kuisioner ini akan dijelaskan pada Tabel 1. Pengisian pada kuisioner cukup diisi dengan score 1 hingga 4. Hasil dari kuisioner ini kemudian akan digunakan sebagai acuan untuk solusi yang akan diimplementasikan pada kasus MV. Gili Cat II.

*Tabel 1 Solution Criteria*

| No. | Criteria | Score |
|---|---|---|
| 1 | Probability of Recurrence | 1 (98-1%) to 4 (-2%) |
| 2 | Ease of Implementation | 1 (Difficult) to 4 (Easy) |
| 3 | Effectiveness | 1 (Not Eff.) to 4 (Very Eff.) |
| 4 | Total Cost | 1 (Expensive) to 4 (Low-Cost) |

## B. Deskripsi Kriteria

- Probability of Recurrenece: Kemungkinan terjadinya kasus yang serupa terulang kembali. Maksudnya ialah, apabila suatu solusi diimplementasikan maka seberapa besar kemungkinan terjadinya kasus tersebut dapat terulang kembali.
- Ease of Implementation: Kemudahan dalam implementasi. Makudnya ialah, seberapa sulit solusi tersebut diimplementasikan.
- Effectiveness: Efektifitas. Maksudnya ialah, seberapa efektifkah solusi tersebut apabila diimplementasikan..
- Total cost: Total biaya. Maksudnya ialah, seberapa besar biaya yang dikeluarkan apabila solusi tersebut diimplementasikan.

Salam Ricard Diago Sambuaga

Mahasiswa J. T. Sistem Perkapalan, ITS.

**Contoh Pengisian Kuisioner:**

| Cause | Solution | Comment | Criteria (1) | Criteria (2) | Criteria (3) | Criteria (4) |
|---|---|---|---|---|---|---|
| • Bad electrical wiring system<br>• Tightening battery using a belt tied manually<br>• Wood boards and sponges used as a prop for battery<br>• Switch and contacts pole aren't protected with isolator<br>• Battery spaces in not good condition<br>• There is a gap between battery spaces and refueling pipeline space.<br>• Lack of ship grounding<br>• Static electricity in the area of the tank and hull | Recommendation about electrical system design | | 1 | 4 | 3 | 2 |

**Form Pengisian Kuisioner:**

| Cause | Solution | Comment | Criteria (1) | Criteria (2) | Criteria (3) | Criteria (4) |
|---|---|---|---|---|---|---|
| • Bad electrical wiring system<br>• Tightening battery using a belt tied manually | Recommendation about electrical system design | ` | | | | |

| Cause | Solution | Comment | Criteria (1) | Criteria (2) | Criteria (3) | Criteria (4) |
|---|---|---|---|---|---|---|
| • Wood boards and sponges used as a prop for battery<br>• Switch and contacts pole aren't protected with isolator<br>• Battery spaces in not good condition<br>• There is a gap between battery spaces and refueling pipeline space.<br>• Lack of ship grounding<br>• Static electricity in the area of the tank and hull | | | | | | |
| • Not using standards material<br>• Material in not good condition<br>• Not using standards material<br>• There is an insulation tape blocking the hole in the pipe connection<br>• Plastic pipe is inserted between two pipe connections<br>• Venting pipe connection in not good condition<br>• Wood boards and sponges used as a prop for battery | Using standard material | | | | | |

| Cause | Solution | Comment | Criteria (1) | Criteria (2) | Criteria (3) | Criteria (4) |
|---|---|---|---|---|---|---|
| • Refueling pipe in not good condition<br>• Venting pipe folded<br>• Due to the modification, venting pipe folded forcibly<br>• Venting pipe location is difficult to checked<br>• Venting pipe mounting moved positon | | | | | | |
| • Venting pipe location is difficult to checked<br>• No fuel indicator on tank<br>• Refueling pipe in not good condition<br>• Venting pipe mounting moved positon<br>• Lack of appropriate pipeline<br>• Due to the modification, venting pipe folded forcibly<br>• Venting pipe folded<br>• Lack of air circulation (saturated gas)<br>• Refueling isn't using an appropriate pump<br>• There is a fuel spill when refueling | Recommendation about piping system design | | | | | |

| Cause | Solution | Comment | Criteria (1) | Criteria (2) | Criteria (3) | Criteria (4) |
|---|---|---|---|---|---|---|
| • Sounding pipe is closed and no longer used | | | | | | |
| • Ship crews didn't check well<br>• Ship crews didn't check well<br>• Refueling manually<br>• There is a fuel spill when refueling<br>• Ship crews didn't check regularly<br>• Ship crews didn't check regularly | Crews was given special training | | | | | |
| • Ship crews didn't check well<br>• Ship crews didn't check well<br>• Refueling manually<br>• Ship crews didn't check regularly<br>• Ship crews didn't check regularly | Ship owner should recruiting the crew that has been certified | | | | | |
| • Ship crews didn't check well<br>• Refueling manually<br>• Ship crews didn't check well<br>• Ship crews didn't check regularly<br>• Ship crews didn't check regularly | Work procedures based on ISM Code | | | | | |

| Cause | Solution | Comment | Criteria (1) | Criteria (2) | Criteria (3) | Criteria (4) |
|---|---|---|---|---|---|---|
| • Welding on the deck only using spot welding<br>• Connection between hull wrang not exhaustive.<br>• No watertight compartement<br>• Air come into compartement under deck | Welding according to standards | | | | | |

# APPENDIX 4
# Detail Calculation of pump and pipe selection, existing and recommendation of fuel tank design

*“This page intentionally blank”*

General Data of MV. Gili Cat II

| | |
|---|---|
| Length Overall | : 11,69 m |
| Breadth Molded | : 3,42 m |
| Draught | : 0,60 m |
| Depth | : 0,90 m |
| Gross Tonnage | : 6 T |
| Net Tonnage | : - |
| Type | : Passenger Ship |
| Flag | : Indonesia |
| Production Year | : 2001 |
| Production Location | : Australia |
| Construction Material | : Aluminum |

**a. Fuel oil Tank**

| | | | | |
|---|---|---|---|---|
| Gasoline tank capacity | | = | 1500 | l |
| Report Data | | | 1,5 | $m^3$ |
| Tank design | A | = | 0,5 | m |
| | B | = | 0,35 | m |
| | p | = | 4 | m |
| | l | = | 0,9 | m |
| | Vol | = | 1,53 | $m^3$ |

**b. Calculation of Fuel oil transfer pump**

Pump is planned to move gasoline from port to Fuel storage tank for 2 hour

| | | | |
|---|---|---|---|
| time (t) | = | 2 | hour |
| Volume | = | 1,5 | $m^3$ |

pumping capacity (Q) = V/t
= 0,75 $m^3$/ h
= 0,0002 $m^3$/ s
= 12,5 l/min

so the internal diameter (D) of fuel filling pipe and vent pipe are:
Fuel filling pipe = 40 mm 0,04 m
= 1,5748 inch
Vent Pipe = 20 mm

*DNV No.2.21 Craft, Ch.5 Sec.4 C206*

*Filling pipe Internal diameter at least 38mm, vent pipe internal diameter at least 16 mm*

* Filling pipe and Feed pipe are using welded steel pipe combinate with flexible pipe
* Flexible pipe shall satisfy the requirements of ISO 7840 Small craft fire resistant fuel hoses type A1 or A2
* *At least two hose clips fabricated from stainless steel shall be used at each connection on flexible hose*

**c. Selecting Pipe**

The selected pipe based on ANSI for Main Pipe is
Nominal Diameter = B 36.10
Inside Diameter = 40,9 mm
Outside Diameter = 48,3 mm
Thickness = 3,7 mm

*ANSI B36.10 Size 1 1/2*

Q = A x v

v = Q / A
= 0,1659 m/s

## d. Calculation for selecting filling pump

d.1 Head Static (hs)

Head Static (hs) is the diference of length of fuel suction and port .

hs = (port-tank height) + 0.5 [m]
= 1 m

d.2 Head velocity (hv)

Head Velocity (hv) is the difference of flow velocity on suction side and discharge side.

hv = 0 m

d.3 Head pressure of pump (hp)

Head Pressure is the diference of pressure on the suction and discharge. Because the pressure on the both side is same, sp thevalue of hp = 0

hp = 0 m

d.4 Head (suction)

| | | | | | |
|---|---|---|---|---|---|
| * viskositas (u) | = | 0,71 | cst in 37,8°C | C | Cst |
| | = | $n/10^6$ | | 15,6 | 0,88 |
| n | = | 0,00000071 | $m^2/s$ | 37,8 | 0,71 |

* Reynold number (Rn)

Rn = (v*dH)/n Dimana : vs : flow velocity [m/s] 0,1659 m/s
= 0,166 m/s x 0,04 m / 0,71 $m^2/s$ x $10^{-6}$ dH : Main bilge's pipe diameter [mm]

= 9344,8 (Turbulent flow) n : 0,71 x $10^{-6}$ $m^2/s$

Rn < 2320 (Laminar)
Rn > 2320 (Turbulent)

* Friction

We use the colebrrok equation formula to know how much the friction factor of the pipe , here the equation :

friction losses [(1/(f^1/2 )] -2 log ( 2,51/ Re $f^{1/2}$) + (ε)/3,72*D )
Where :
absolute roughness = 0,045 mm (weleded steel pipe)
diameter (D) = 40,9 mm
Reynolds number (R = 9345

if we use the colebrook equation formula calculator , so the friction factor is :
f = 0,03303887

* Major losses (hf) = f x L x v2 / (D x 2g)
Where :
L = Length of pipe suction = 2,3 m
g = Gravitasi = 9,8 $m/s^2$
So :
hf = 0,00261 m

* Minor losses (hm)

| | | | | |
|---|---|---|---|---|
| 1 | Elbow 90° | 2 | 0,75 | 1,5 |

| | | | | |
|---|---|---|---|---|
| 2 | Butterfly Valve | 1 | 0,6 | 0,6 |
| 3 | Strainer | 1 | 2,5 | 2,5 |
| | | S nk | | 4,6 |

So, Minor Losses (hm) = $\Sigma$ nk x $v^2$ / 2g
= 0,0065 m

* Total Head Suction

Total Head Suction = Major losses (hf) + Minor losses (hm)
= 0,00261 + 0,0065
= 0,01 m

d.5 Head (discharge)

* Minor losses (hm)

| | | | | |
|---|---|---|---|---|
| | | | | |
| 1 | SDNRV remotely | 1 | 1,35 | 1,35 |
| | | S nk | | 1,35 |

So, Minor Losses (hm) = $\Sigma$ nk x $v^2$ / 2g
= 0 m

* Total Head Discharge

Total Head Discharge = Major losses (hf) + Minor losses (hm)
= 0,00261 + 0
= 0,00 m

d.6 Total Head Losses

Total Head Losses = Head Suction + Head Discharge
= 0,01 m

d.7 Head Total

Head Total = hs + hv + hp + Head Losses

= 1,01 m

d.8 The Selected Pump's Spesification

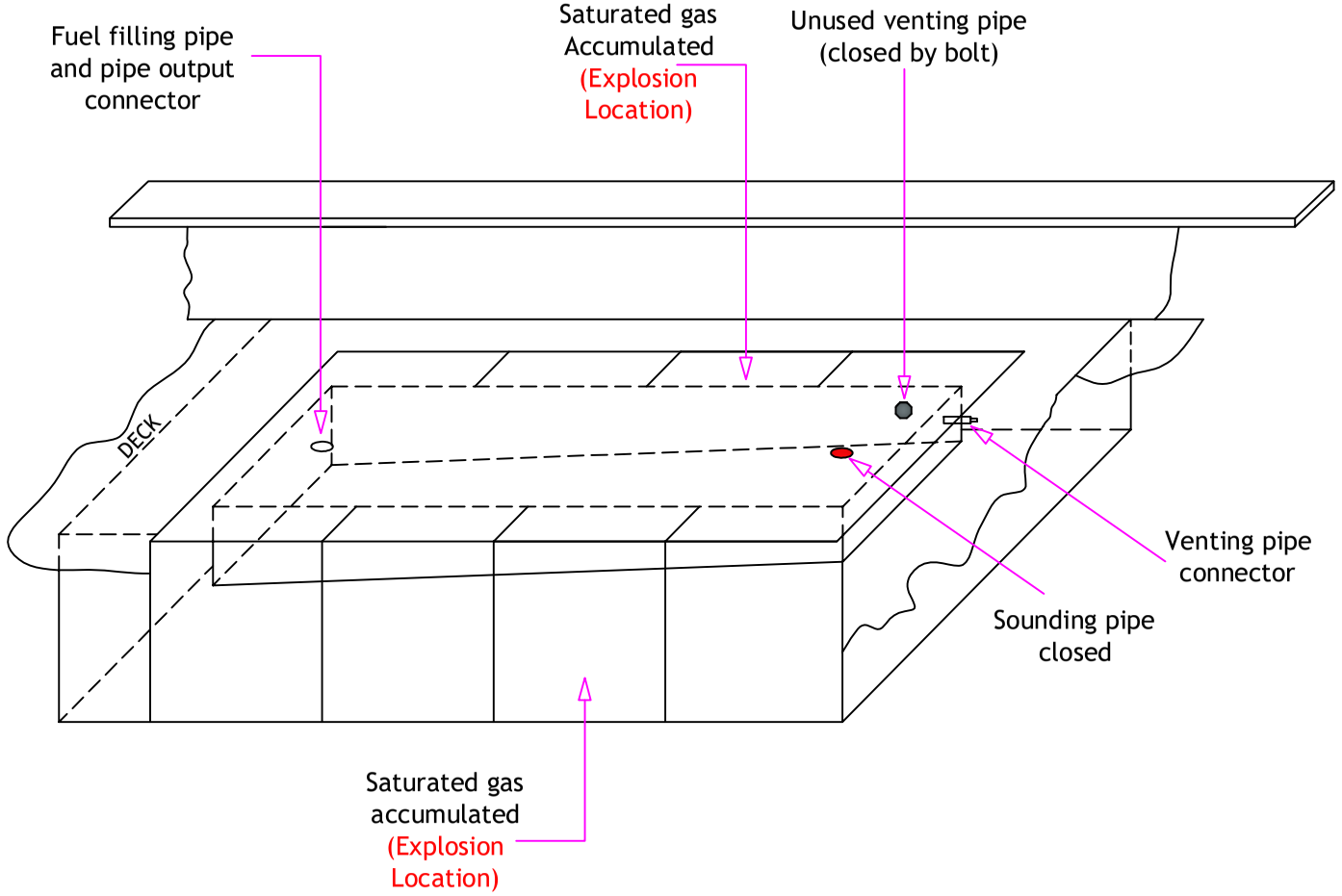
Based on the calculation

Head : 1,01 m

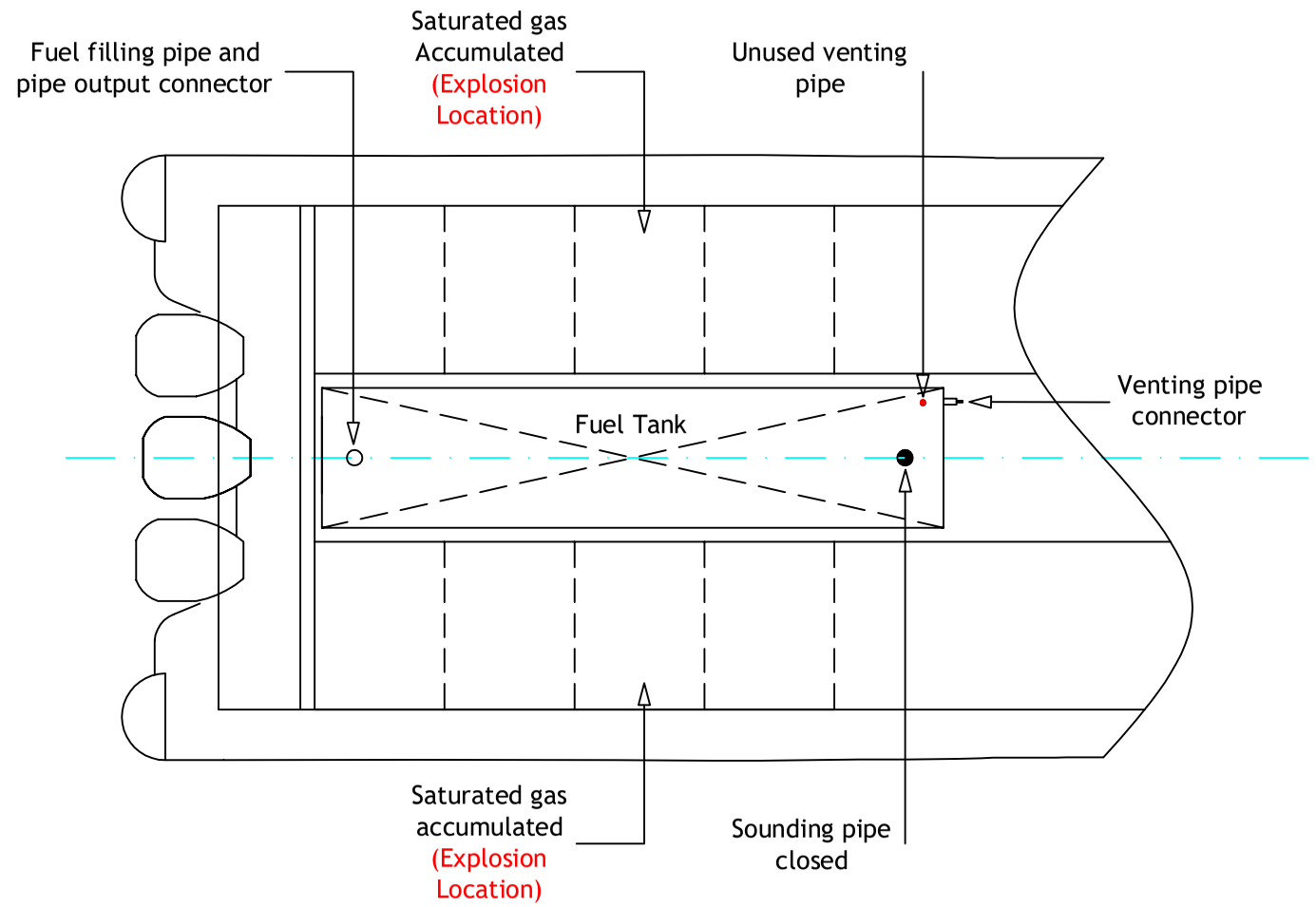
Capacity : 0,75 $m^3$/ h

Fuel oil filling pump

| | | | | | | |
|---|---|---|---|---|---|---|
| Merk | : HAINA PUMPS | | Motor | : | 3 phase | |
| Type | : CYB-S-25-27 | | Frequency | : | 50 | Hz |
| Qapacity | : 3 | m3 / h | Model | : | YB801-2 | |
| Head | : 27 | m | Power | : | 0,75 | kW |
| RPM | : 2900 | rpm | | | | |
| Shaft Power | : 0,6 | kW | | | | |




# TOP VIEW



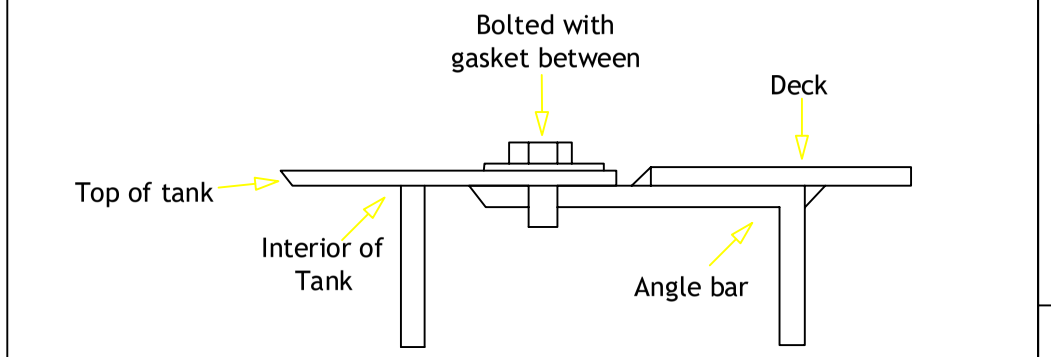

| PRINCIPAL DIMENSION | |
|---|---|
| Loa | 11,69 m |
| Breadth | 3,42 m |
| Drought | 0,60 m |
| Depth | 0,90 m |
| GT | 6 T |
| NT | - T |
| Type | Passenger Ship |
| Flag | Indonesia |
| Prod. Year | 2001 |
| Prod. Loc. | Australia |
| Cons. Mat. | Aluminum |

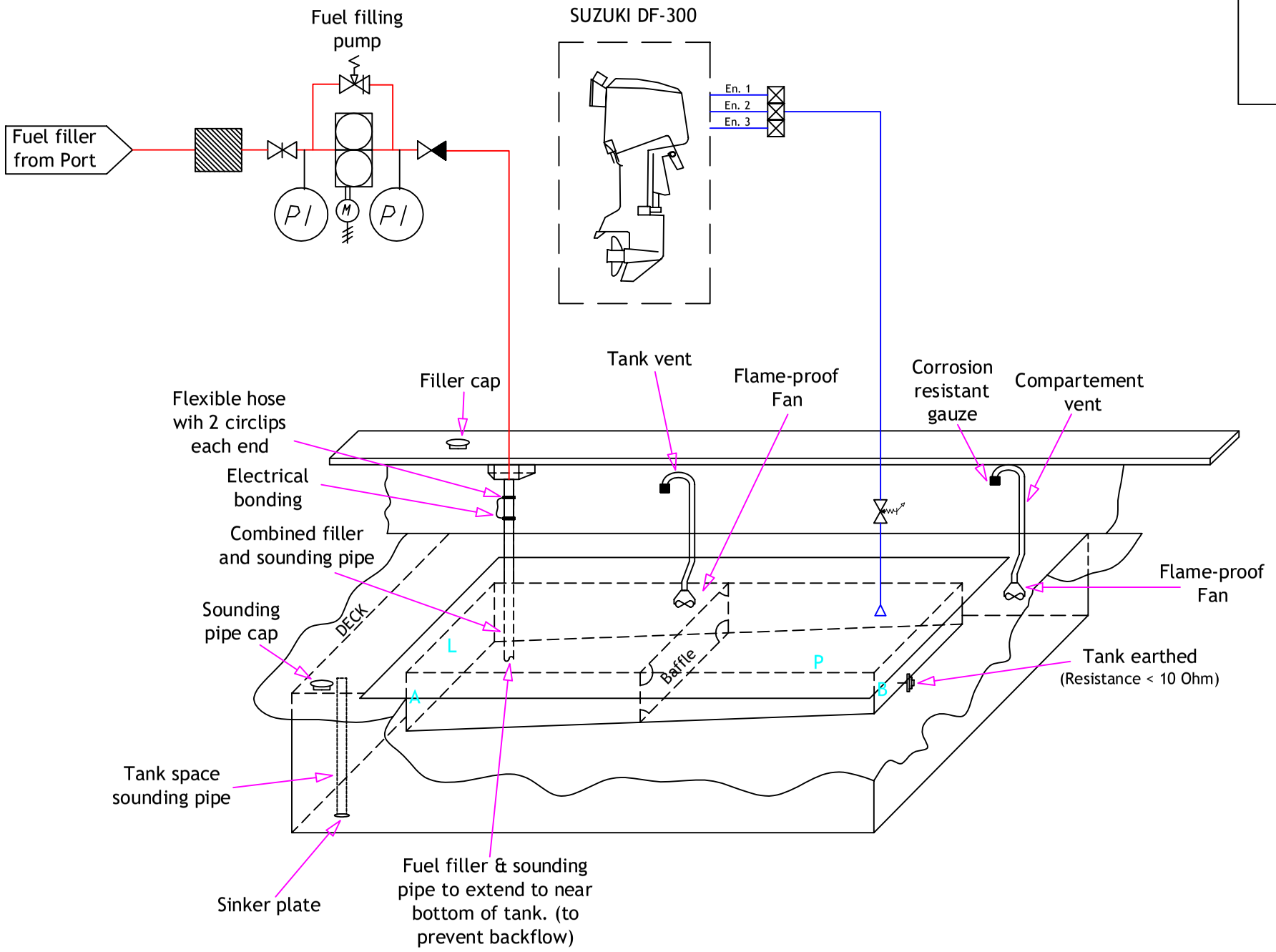
DEPARTMENT OF MARINE ENGINEERING
DOUBLE DEGREE PROGRAM
INSTITUT TEKNOLOGI SEUPUH NOPEMBER - HOCHSCHULE WISMAR

MV. Gili Cat II

Existing Fuel Oil System

| 4213101046 | Scale : | Signature | Date |
|---|---|---|---|
| Student : Ricard Diago Sambuaga | | | |
| 1st Supervisor : Dr. Eng. Trika Pitana, S.T., M.Sc. | | Sheet NO. | Rev. 0 | Status |
| 2nd Supervisor : Ir. Dwi Priyanta, M.SE. | | | |




| TANK DIMENSION | |
|---|---|
| A | 0,50 m |
| B | 0,35 m |
| P | 4,00 m |
| L | 0,90 m |

| PRINCIPAL DIMENSION | |
|---|---|
| Loa | 11,69 m |
| Breadth | 3,42 m |
| Drought | 0,60 m |
| Depth | 0,90 m |
| GT | 6 T |
| NT | - T |
| Type | Passenger Ship |
| Flag | Indonesia |
| Prod. Year | 2001 |
| Prod. Loc. | Australia |
| Cons. Mat. | Aluminum |

DEPARTMENT OF MARINE ENGINEERING
DOUBLE DEGREE PROGRAM
INSTITUT TEKNOLOGI SEUPUH NOPEMBER - HOCHSCHULE WISMAR

# MV. Gili Cat II

## Fuel Oil System Recommendation

| 4213101046 | Scale : | Signature | Date |
|---|---|---|---|
| Student : Ricard Diago Sambuaga | | | |
| 1st Supervisor : Dr. Eng. Trika Pitana, S.T., M.Sc. | | | |
| 2nd Supervisor : Ir. Dwi Priyanta, M.SE. | | Sheet NO. | Rev. 0 / Status |

# AUTHOR BIOGRAPHY

The author was born in Tangerang, September 6th, 1996 as the second child of 4 siblings. His father is Mr. Ansori and his mother is Mrs. Ramiyah. The author has completed the formal education in SD Citra Islami, Islamic Village Tangerang, SMP Citra Islami, Islamic Village Tangerang, and SMA International Islamic Boarding School Republic of Indonesia (IIBS RI), Bekasi. The author continued his study to bachelor degree in Marine Engineering Double Degree (DDME) program of Institut Teknologi Sepuluh Nopember (ITS), Indonesia and Hoschule Wismar, Germany. The author took area of expertise in Marine Reliability, Availability, Management, and Safety (RAMS). During the college, the author was active in academic and non-academic activities such as: Student Activity Unit Maritime Challenge, Committee of Indonesia Maritime Challenge 2015 (National), 1st Winner of Dragon Boat Race Marine Icon 2015 (National), and Participant of Summer School Program, Kobe University, Japan. The author has done on the job training in PAL Indonesia Ltd. Shipyard, Surabaya and Titan Wijaya Ltd. Coal Port, North Bengkulu.